SEWAGE WORKS JOURNAL

Vol. IV JULY, 1932 No. 4

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A Quarter Century in Chicago—*Pearse*

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Wet Flowers for Sewage Works—*Phelps*

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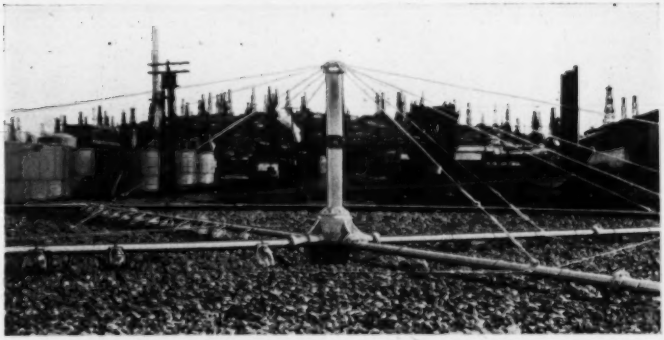

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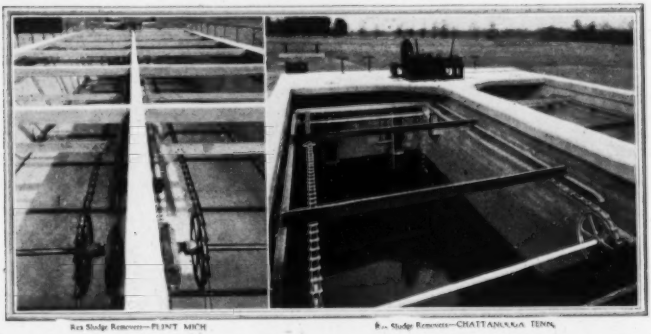

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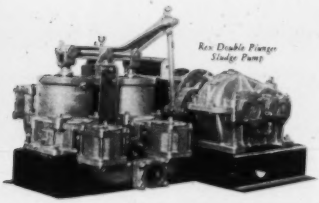

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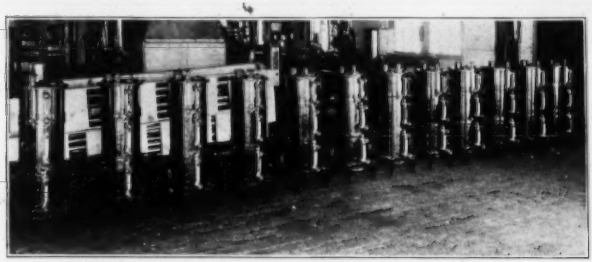

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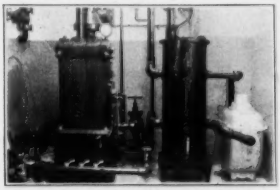

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Sewage Research

Heat and Energy Relations in the Digestion of Sewage Solids
III. Effect of Temperature of Incubation Upon the Course of Digestion

By Gordon M. Fair and Edward W. Moore

Associate Professor of Sanitary Engineering and Research Assistant in Sanitary Engineering, The Harvard Engineering School, Cambridge, Mass.

In the preceding article[21,*] of this series it was shown that the course of sludge digestion as traced by gas production is an S-shaped, or ogee curve which may be formulated mathematically. Two formulations were presented: (1) an autocatalytic equation, or equation of a unimolecular reaction accelerated by the catalytic activity of the products of reaction; (2) a two-stage formulation, or equation of a discontinuous unimolecular reaction, preceded by a discontinuous equation of constant rate of increase.

While recognizing the fact that the autocatalytic equation appeared to interpret best the kinetics of the sludge-digestion process, the two-stage formulation was proposed for use in engineering studies because of its simplicity, directness and adequacy. It is the purpose of this paper to show the application of this two-stage formulation in evaluating the effect of the temperature of incubation upon the course of sludge digestion.

As presented in the preceding paper the two-stage formulation includes two discontinuous equations defined by four constants (K_1, K_2, t_t and L) as follows:

(1) $\log G = \log \frac{1}{2} L - K_1 (t_t - t)$ Limits: $(t = 0)$ to $(t = t_t)$

(2) $\log L_t = \log \frac{1}{2} L - K_2 (t - t_t)$ Limits: $(t = t_t)$ to $(t = \infty)$

where

G = amount of gas produced in time t;
L = total amount of gas generated during digestion (theoretical limit);
L_t = $L - G$ = amount of gas remaining to be produced after digestion has proceeded for time t;
K_1 = first-stage gasification constant;
K_2 = second-stage gasification constant;
t_t = time elapsing between start of digestion and transition from first to second stage of digestion, the amount of gas produced up to this time being $\frac{1}{2} L$.

* *Numbers refer to references at the end of this paper.*

TABLE I

SUMMARY OF EXPERIMENTAL RESULTS FOR SERIES I TO VI

Solids Derived from Plain Sedimentation

Temp., °F.	Series I							Series II							Series III							Temp., °C.
	K_1	K_2	K	t_1	t_{90}	L_0	L	K_1	K_2	K	t_1	t_{90}	L_0	L	K_1	K_2	K	t_1	t_{90}	L_0	L	
77	.0223	.0310	.0263	25.8	48.1	836	821	.0881	.0540	.0694	10.9	24.2	743	743	.0545	.0410	.0477	17.1	34.4	874	874	25
86	.0191	.0366	.0254	34.3	53.8	898	886	.1263	.0562	.0855	10.2	22.8	692	682	.0586	.0540	.0568	17.0	30.0	878	868	30
95	.0212	.0285	.0244	31.9	56.3	873	873	.0989	.0732	.0887	14.4	24.0	672	672	.0762	.0519	.0644	14.6	28.3	889	864	35
104	.0324	.0410	.0355	30.0	46.9	878	838	.1210	.0780	.1011	10.2	19.1	715	700	.0879	.0495	.0693	15.2	29.6	931	895	40
113								.1230	.0676	.0919	8.8	19.4	759	740	.0558	.0451	.0506	16.3	31.8	916	916	45
122								.1436	.0700	.1001	7.0	17.1	768	762	.0666	.0425	.0530	13.1	30.0	1018	1018	50

Excess Activated Sludge

Temp., °F.	Series IV							Series V							Series VI							Temp., °C.
	K_1	K_2	K	t_1	t_{90}	L_0	L	K_1	K_2	K	t_1	t_{90}	L_0	L	K_1	K_2	K	t_1	t_{90}	L_0	L	
77	.0239	.0113	.0155	31.6	94.2	216	216	.0128	.0122	.0125	39.2	95.4	181	190	.0301	.0417	.0341	32.0	49.0	719	719	25
86	.0225	.0135	.0168	30.5	82.1	232	232	.0193	.0157	.0173	35.0	79.2	212	222	.0417	.0331	.0381	28.5	50.0	852	872	30
95	.0533	.0165	.0263	16.4	61.5	249	249	.0132	.0171	.0153	36.2	77.5	172	172	.0658	.0515	.0583	12.5	26.3	794	794	35
104	.1105	.0167	.0333	9.6	54.4	283	273	.0300	.0217	.0239	17.5	65.4	204	204	.0770	.0536	.0662	15.5	28.8	832	806	40
113	.1000	.0271	.0451	8.5	35.2	304	386	.1106	.0165	.0362	11.0	52.7	313	313	.0766	.0658	.0724	16.8	27.5	733	713	45
122	.1950	.0272	.0589	6.2	32.7	338	323	.0702	.0209	.0319	9.6	42.9	307	303	.1105	.0720	.0880	6.8	16.7	989	959	50
140	.0712	.0522	.0589	7.6	21.7	369	339	.0858	.0149	.0285	10.8	56.3	309	309	.1021	.0702	.0865	10.5	20.5	910	870	60

K_1 = first-stage gasification constant;
K_2 = second-stage gasification constant;
K = mean of K_1 and K_2 weighted according to length of first stage and second stage on a basis of 90 per cent complete digestion;
t_1 = length of first stage, in days;
t_{90} = time required for 90 per cent complete digestion, in days;
L_0 = observed total gas production, in liters per kilogram of raw volatile solids;
L = formulated total gas production, in liters per kilogram of raw volatile solids.

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This formulation has been applied to the results of the digestion experiments upon which this paper is based. These experiments comprise: (*a*) a preliminary series (Series I) in which solids derived from plain sedimentation (generally called fresh solids in this paper) were seeded with Imhoff sludge and digested at temperatures of 77, 86, 95, 104, 113, 122 and 140° F.; (*b*) three series (Series II, III, VI) in which fresh solids were digested after seeding with the residue produced at like temperature in the preceding series (Series I, II, V, respectively); (*c*) two series (Series IV, V) in which excess activated sludge was digested after seeding with the residue produced at like temperature in the preceding series (Series III, IV, respectively); (*d*) a final series (Series VII) in which fresh solids were added to the seven residues of Series VI produced at temperatures varying from 77° to 140° F., all seven mixtures then being digested at a like temperature of 122° F. The experiments were of the batch type and were continued until only small quantities of gas were evolved. The experimental apparatus and procedure are described in the preceding paper[21] of this series.

TABLE II

SUMMARY OF EXPERIMENTAL RESULTS FOR SERIES VII—SOLIDS DERIVED FROM PLAIN SEDIMENTATION SEEDED WITH RESIDUES OF SERIES VI BUT INCUBATED AT A TEMPERATURE OF 122° F. (50° C.)

Temperature at Which Seeding Sludge Was Produced								
° F.	° C.	K_1	K_2	K	t_f	t_{90}	L_0	L
77	25	0.1170	0.1290	0.1203	14.0	19.4	679	679
86	30	0.0906	0.1116	0.0961	17.2	23.3	696	716
95	35	0.0835	0.0980	0.0873	19.3	26.5	646	666
104	40	0.0938	0.1245	0.1020	15.6	21.3	661	661
113	45	0.1283	0.1103	0.1201	7.9	14.3	691	681
122	50	0.1470	0.0716	0.1044	7.5	17.3	664	664
140	60	0.1043	0.0960	0.1010	11.0	18.3	695	695

For explanation of symbols see Table I.

Experimental Results.—The results obtained in the seven series of experiments are summarized in Tables I, II and III. For purposes of description and comparison the digestion characteristics observed are expressed in Tables I and II in terms of the constants, K_1, K_2, t_f and L, which define the two-stage formulation of the course of digestion. To these are added the time t_{90} required to carry digestion to 90 per cent completion, L_0 the observed total volume of gas produced (as against L the value best fitting the formulation) and K the average of K_1 and K_2 weighted according to the length of the first stage and the length of the second stage on a basis of 90 per cent complete digestion.

Table III gives a summary of the characteristics of the sludges em-

TABLE III

SUMMARY OF CHARACTERISTICS OF SLUDGES EMPLOYED AND AVERAGE RESULTS OF DIGESTION

	Series II	III	V	VI	IV	I	VII
Raw Sludge							
Origin	F	F	L	F	L	F	F
Volatile-matter content—%	77.6	82.3	64.2	68.5	69.0	82.4	65.8
Energy coefficient C*	27.8	25.4	26.6	23.8	23.8	29.0	26.1
Seeding Sludge							
Origin	I	II	IV	V	III	FD	VI
Ratio of volatile matter in raw sludge to volatile matter in seeding sludge	0.84	2.28	1.80	1.33	1.92	1.44	1.66
Seeded Sludge Mixture							
Volatile-matter content—%	61.0	65.6	61.0	53.3	62.9	53.7	49.5
Fuel value—B. t. u. per lb. dry solids	6700	7100	6300	5600	6200	6700	5000
Energy coefficient C*							
Initial	29.6	27.1	26.1	28.0	24.7	30.3	26.1
Final	30.4	26.4	26.5	24.4	25.2	30.9	28.5
Gas production—cu. ft. per lb. raw vol. matter							
Total	19.6	14.7	3.7	13.1	4.3	13.6	10.8
Methane	7.7	9.9	3.1	8.7	2.7	9.3	7.2
Carbon dioxide	3.9	4.8	0.6	4.4	1.6	4.3	3.6
Weighted mean gasification constant—K							
Minimum	0.0694	0.0477	0.0125	0.0341	0.0155	0.0244	0.0873
Maximum	0.1011	0.0693	0.0362	0.0880	0.0589	0.0355	0.1203
Mean	0.0895	0.0569	0.0229	0.0595	0.0326	0.0279	0.1005
Digestion period—days							
First stage	10.3	15.5	24.8	18.7	17.1	30.5	13.6
Second stage to 90% completion	10.8	15.2	44.1	14.3	42.9	20.8	6.8
Total to 90% completion	21.1	30.7	68.9	33.0	60.0	51.3	20.4
Heat of activation—μ							
25–40° C.	4900	4900	10000	7500	10000	....	....
45–50° C.	3500	2300	10000	7500	10000	....	....
Constant of total gas yield—a	0.0072	0.0072	0.024	0.0073	0.023	....	....
General condition of seeding	Good	Good	Good	Poor	Poor	Poor	Poor

NOTE: With exception of Series VII in which a temperature of 122° F. was employed, the seeded sludge was incubated at temperatures of 77, 86, 95, 104, 113, 122 and, in some cases, 140° F. The values recorded in this table are averages for batches digested between 77° and 122° F., except for Series I which includes temperatures between 77° and 104° F. only, and Series VII which was restricted to a temperature of 122° F.

* Computed from the formula $Q = CP^{4/3}$ [see Article I of this group of papers: THIS JOURNAL, IV, 242 (1932)].

F = Fitchburg, Mass. Sludge from sedimentation compartments of Imhoff tanks.
FD = Fitchburg, Mass. Sludge from digestion compartments of Imhoff tanks.
L = Lawrence, Mass. Experimental Station. Excess activated sludge.

ployed in the experiments and includes the average observed values of gas production, the weighted mean gasification constant K, the digestion period t and the heat of activation μ.

Effect of Temperature Upon Rate of Gasification.—It is a well-known chemical fact that the velocity of a reaction increases as the temperature is raised, some reactions being speeded up more than others[1,3]. This temperature effect has been formulated by Arrhenius[1,2] as follows:

$$\frac{d(\log_e K)}{dT_a} = -\frac{\mu}{RT_a^2} \tag{1}$$

where

K = the reaction velocity constant;
T_a = the absolute temperature (° C. + 273.1);
R = the gas constant (R = 1.9885 cal.);
μ = the heat, or energy, of activation, or temperature characteristic. (If R is expressed in calories, μ becomes calories per gram molecule.)

Calling K_T and $K_{T'}$ the reaction velocity constant at any absolute temperature T and T', respectively, the Arrhenius equation in its integrated form may be written:

$$\log \frac{K_{T'}}{K_T} = \frac{\mu}{2.3026\ R}\left(\frac{1}{T_a'} - \frac{1}{T_a}\right) \tag{2}$$

By writing this equation as:

$$\log K_T = \left(\frac{\mu}{2.3026\ RT_a'} + \log K_{T'}\right) - \frac{\mu}{2.3026\ R}\frac{1}{T_a} \tag{3}$$

it follows that a plot of log K_T as the ordinate against $\frac{1}{T_a}$ as the abscissa will yield a straight line relationship from which the value of μ may be determined as the slope of the line multiplied by 2.3026 R, or 4.58. Such a plot is shown in Figure 1* for the values of K obtained in Series II to VI. The fact that the observed points approximate a straight line is presumptive evidence that the influence of temperature upon K may be formulated in accordance with the Arrhenius equation and hence defined by the value of μ.

It should be noted that K, the weighted mean of K_1 and K_2, is made the basis of this study. This has been done because the observed values of K_1 and K_2, although they exhibit a trend toward increasing magnitudes at higher temperatures, are not sufficiently regular to justify mathematical analysis. This circumstance is probably due to the fact that the reactions associated with the decomposition of sludge particles are limited in part by the extent of surface presented by the sludge as a whole. In the relatively small samples employed in the experiments, uniformity of surface was probably not obtained. More consistent results might have been noted if the sludge had been macerated before distributing it between the digestion vessels.

When K_1 and K_2 are combined to form a weighted mean such as K, values fairly regular in trend are obtained. The reason for this is that departures from the expected values of K_1 are offset, more or less, by departures of K_2 in the opposite direction, a high value of K_1 thus being associated with a low value of K_2 and *vice versa*.

* Ordinary temperatures in ° C. are marked on the abscissa, the coördinate interval being determined by the reciprocal of the absolute temperature.

A study of Tables I to III and of Figure 1 brings out a number of interesting numerical facts relative to the effect of temperature upon the rate of sludge digestion. To begin with, there appears to be considerable difference between the response of activated sludge and fresh sludge to increased temperatures. Thus the observed value of μ for temperatures of 25–40° C. (77–104° F.) is 10,000 for activated sludge against 4900 for plain-sedimentation solids. This means that the ratio of K at 40° C. (104° F.) to K at 25° C. (77° F.) is 2.2 in the case of activated sludge and only 1.5 in the case of fresh solids. At temperatures of 45° C. (113° F.) and 50° C. (122° F.) this difference in behavior between the two types of solids becomes even more marked, for while μ persists for activated sludge at a

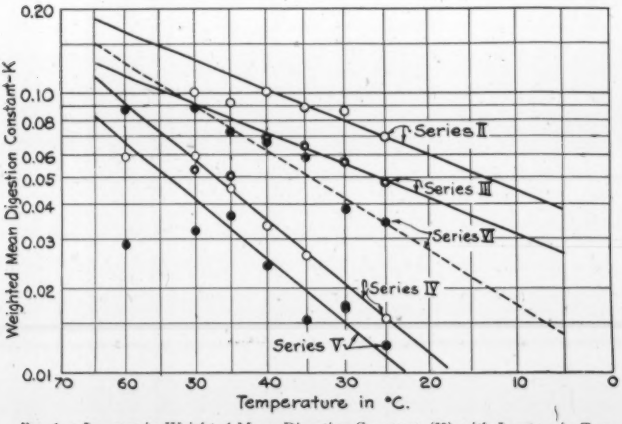

FIG. 1.—Increase in Weighted Mean Digestion Constant (K) with Increase in Temperature of Incubation. Vertical scale: Logarithmic. Horizontal scale: Reciprocal of Absolute Temperature.

value of 10,000 it drops 30 to 50 per cent below the value of 4900 in the digestion of fresh solids. At 60° C. (140° F.) a drop in the value of μ occurs also for activated sludge. These drops in μ at higher temperatures are observed also in biological processes other than sludge digestion.[5,13] An explanation advanced by Crozier[7] is that a reaction, or group of reactions, characterized by a lower value of μ becomes dominant at higher temperatures. Conversely, there may be a rise in μ at temperatures lower than those employed in this study.

In the digestion of the two series of well-seeded fresh solids (Series II

and III) the values of μ were observed to be identical below a temperature of 40° C. (104° F.); in the digestion of the two series of activated solids (Series IV and V) this was found to be true up to a temperature of 50° C. (122° F.), although the seeding material in Series IV contained no digested activated sludge. In Series VI, in which the seeding material was chiefly digested activated sludge, and the material to be digested was fresh sludge, a value of μ equalling 7500, about midway between that of activated and fresh solids was observed up to a temperature of 50° C. (122° F.).

Although there is much debate as to the fundamental significance of μ, it has become evident from experimental work that reactions of the same type are characterized by the same magnitude of μ and that in any process composed of a chain of reactions, the effect of temperature upon the rate of the process will be measured by a value of μ which holds for the slowest, or controlling, reaction of the chain. Hence the determination of μ for a complex process, such as sludge digestion, may be expected to give some information on the type of reaction that controls the process.

With this in view many investigators, notably Crozier[6-9,12,14,15] and his co-workers, have applied the concept of the Arrhenius equation to numerous different physiological activities of living organisms. Crozier[7,14] has summarized this work and expressed the belief that the value of μ may be employed to identify the controlling reaction in protoplasmic activity.

Some of the values of μ reported in the literature are brought together in Table IV. To these have been added the values observed by the authors for sludge digestion.

In comparing the values of μ for sludge digestion with those for other biochemical processes (Table IV) it must be remembered that the authors' figures of μ for sludge digestion have reference to the increase with temperature of a weighted mean K of the first-stage and second-stage gasification constants K_1 and K_2. Interpretation of the values of μ must, therefore, be curtailed to the remark that the observed values approach the range of enzymic processes and oxidation by hydrolysis. If direct use of K_1 and K_2 were possible more definite conclusions might be drawn. It follows from the way K is computed that the values of μ for K_1 and K_2 individually are likely to be higher and lower, respectively, than those recorded for K.

So far as the general magnitudes of K_1, K_2 and K are concerned it appears from Table I and III and from Figure 1 that at the lower temperatures (77° F., 25° C.) these coefficients of the rate of gasification are relatively much higher for well-seeded fresh solids (Series II and III) than for activated sludge (Series V), but that this advantage is reduced appreciably by digestion at higher temperatures. The value of K_2 which traces the unimolecular stage of digestion is generally smaller than that of K_1. Its value for fresh sludge of about 0.05 at 77° F. makes it about

TABLE IV

SOME MAGNITUDES OF μ, THE HEAT OF ACTIVATION, OR TEMPERATURE CHARACTERISTIC

Reaction	μ	Temperature Range, ° C.	Reference Number*
Oxidation			
Catalyzed by iron	16100	Usually below 15	7
Catalyzed by OH ion	11000–12000	Usually above 15	7
By dehydrogenation	16700	30–60	6
By hydrolysis	8000	Usually above 15	10
Enzymic Processes			
Tryptic cleavage of casein	7400	Not given	2
Saponification of cottonseed oil by lipase	7500	Not given	2
Destruction of H_2O_2 by catalase	6200	Not given	2
Haemolysis of blood corpuscles by sodium oleate	3800	4–36.3	2
Physical Processes			
Diffusion of oxygen in water	2700	2.5–35.1	14
Decomposition of Sewage			
Biochemical oxygen demand	7400–8500	2–37	16
Sludge digestion			
Plain-sedimentation solids	(1800)	(10–20)	19†
	4900	25–40	—
	2300–3500	45–50	—
Activated solids	10000	25–50	—

* For list of references see end of paper.

† Computed from average curve given by Metcalf and Eddy.

half the value of the deoxygenation* constant of sewage polluted waters, or of sludge deposits in streams (aerobic decomposition). At like temperature the value of K_2 is about 0.012 for activated sludge or about one-tenth the value of the deoxygenation constant defining the rate of aerobic decomposition.

Effect of Temperature on Gas Yield.—When the values for total gas production (L) recorded in Table I are plotted, as in Figure 2, it is apparent that the yield of gas becomes somewhat greater as the temperature of incubation is raised. The formulated limit of gas production (L) is plotted in Figure 2 rather than the observed value (L_0) because L is employed in the two-stage formulation of gasification. The difference between observed and formulated values is usually small, the observed value generally exceeding the formulated value by less than 5 per cent. This difference may represent gasification by a process other than the controlling one.

In view of the irregularity of the observations shown in Figure 2, a straight-line relationship of the form $L_T = L_T'[1 + a(T - T')]$ may be chosen to generalize the results. In this relationship L_T = total gas

* A unimolecular reaction.

production at a temperature of $T°$ C.; L_T' = total gas production at a temperature of $T'°$ C.; a = a constant of total gas yield.

Chosing a reference temperature $T' = 20°$ C., the equation becomes:

$$L_T = L_{20} [1 + a (T - 20)]$$

For well-seeded fresh sludge the value of a was observed to be about 0.0072 while for activated sludge it was about 0.024 or more than three times as great. Here again, therefore, activated sludge shows itself to be more responsive to digestion at elevated temperatures than does plain-

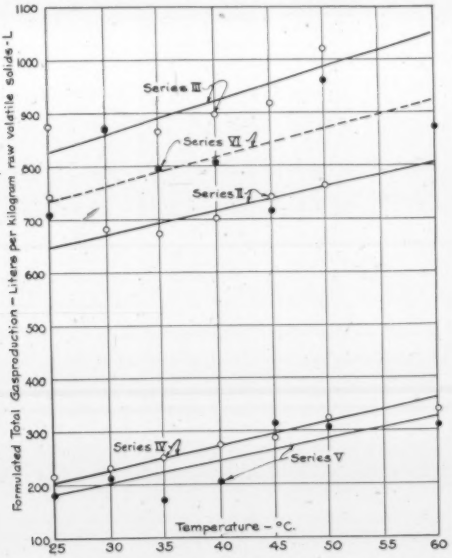

FIG. 2.—Increase in Formulated Total Gas Production with Increase in Temperature of Incubation.

sedimentation sludge. So far as the magnitude of L at any particular temperature is concerned, however, the yield of gas per unit of raw volatile matter is very much lower for activated sludge than for fresh solids. As shown in Tables I and III well-seeded plain-sedimentation sludge produced between three and four times as much gas, or between two and three times as much methane, as activated sludge.

The values of a = 0.0072 for fresh solids and 0.0024 for activated sludge

may be compared with the value of 0.02 reported by Theriault[16] for biochemical oxygen demand. Rudolfs[17,18] has reported values of L for fresh solids which indicate a value $a = 0.01$ between temperatures of 20° and 55° C. (68 and 131° F.) and a value $a = 0.04$ between 10° and 35° C. (50° and 95° F.). Here again, therefore, a rise in temperature appears to be of greater moment within the range of low temperatures than within that of thermophilic ones.

Importance of Proper Seeding.—If the effect of temperature upon the course of sludge digestion is to be evaluated, the seeding material employed must originate not only from similar sewage solids but also from the same temperature of incubation. This is illustrated in a number of different ways by the data in Tables I–III.

Directing our attention to those parameters that measure rate of digestion (K_1, K_2, K, t_t and t_{90}) we observe the marked effects produced by seeding raw fresh solids with digested fresh sludge originating at the temperature of incubation. In Series II (properly seeded), for example, the average time of digestion (90 per cent complete) is 21.1 days against 51.3 days in Series I (improperly seeded). Similar differences can be pointed out for the other parameters of rate of digestion at individual temperatures and for the two series as a whole. Comparing Series II and III in which similar materials were used and which might, therefore, be expected to yield similar results, it is found that Series III in general lags behind Series II. Examination of Table III shows, however, that the energy coefficient of the seeded sludge mixture was appreciably higher in Series II (average C equals 30.0) than in Series III (average C equals 26.7). This may account for the difference in behavior of the two sludges. Series I in comparison with II and III illustrates the effect of employing for seeding a sludge produced at a low temperature—or probably about 60° F. Series VII exemplifies the results that are obtained at 122° F. by using a seeding sludge produced at both lower and higher temperatures. As shown in Table II, best results were obtained in the vicinity of the temperature at which the seeding material originates. Differences, however, are not so pronounced as in Series I.

Series IV, V and VI show the effects of employing a fresh sludge residue to seed activated sludge and *vice versa*. In each case digestion partakes somewhat of the nature of both constituents: but the raw material is dominant in its influence. Thus Series IV (raw activated sludge seeded with fresh-sludge residue) behaves much like properly seeded activated sludge, and Series VI (raw fresh sludge seeded with activated-sludge residue) approaches properly seeded fresh sludge in behavior. It follows that dissimilar material may be employed for seeding purposes but that the results obtained will not run true to type.

An effect not concerned directly with the temperature, but, as previously

indicated, of importance in interpreting results is the correlation between the parameters of rate of digestion and the energy coefficient C of the seeded sludge mixture. The significance of this coefficient has been discussed in Article I[20] of this group of papers. As shown in Table III the rate of digestion of properly seeded sludge varies directly as the value of the energy coefficient. In the case of improperly seeded solids the effect of C is masked by the conditions of seeding.

If we direct our attention to the parameters measuring the liberation by digestion of energy in the form of gas (L_0 and L) we note that for well-seeded material there is a direct correlation between the various parameters of the energy content of the sludge mixtures (Table III) and the gas production. Just what the energy balance is will be the subject of the succeeding paper of this series.

Summary and Conclusions

The analysis of the data presented in this paper for the purpose of evaluating the effect of temperature upon the course of sludge digestion is not intended to serve any purpose beyond that of an orientation study. General trends and their mathematical pictures are indicated, but more extensive, as well as more refined work will have to be done before the parameters of digestion are satisfactorily established in magnitude and variability. Some of the variations in the authors' data may be ascribed to experimental procedure. One lesson learned in particular is that methods must be devised for rendering sewage solids more homogeneous both in size and character before distributing them through the digestion vessels of experimental apparatus. Another, better anticipated in the authors' study, is the importance of establishing proper seeding material. Ultimately individual values may be expected to become sufficiently reliable to replace the weighted means employed in the present paper.

The analysis of data included in this paper indicates the following:

1. The influence of temperature upon rate of digestion may be formulated in accordance with the Arrhenius equation and hence defined by the value of μ, the heat, or energy, of activation or temperature characteristic.

2. The observed magnitude of μ between temperatures of 77° and 104° F. was in the vicinity of 10,000 for activated sludge and 5000 for plain-sedimentation sludge. Hence temperature is appreciably more influential in accelerating the digestion of activated sludge than that of plain-sedimentation sludge. Activated sludge, however, does not digest so well in general as plain-sedimentation sludge. A drop in the value of μ occurred at 122° F. in the case of plain-sedimentation sludge and at 140° F. in that of activated sludge. Higher values of μ will probably be observed below 77° F.

3. Since reactions of the same type seem to be characterized by the

same value of μ, the values observed in sludge digestion may give some information on the type of reaction that controls the process. The observed values approach the range of enzymic processes and oxidation by hydrolysis.

4. The ultimate yield of gas is increased slightly as the temperature of incubation is raised. A straight-line relationship $L_T = L_{T'}[1 + a(T - T')]$ generalizes the results. The observed value of a was 0.0072 for plain-sedimentation sludge and 0.024 for activated sludge. Here again temperature seems to affect activated sludge more than it does fresh sludge.

5. Seeding is of importance both in relation to the general nature of digested sludge employed and the temperature at which it was digested.

In conclusion it should be noted that the effect of temperature upon the course of anaerobic decomposition of sewage solids—called sludge digestion—may be evaluated in much the same way as the course of aerobic decomposition of polluted waters and sludge deposits. Temperature characteristics of similar magnitude will be encountered in both processes. So far as the rate of decomposition at any particular temperature is concerned, however, aerobic decomposition appears to be appreciably faster than anaerobic decomposition.

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New Thoughts in Sedimentation of Sewage*

BY CHESTER A. SMITH

Plain sedimentation is one of the earliest methods of treatment for clarification of water and sewage. It is still an important unit in practically all plants for treatment of water and sewage, and the most economical and efficient method of removing the larger part of suspended or settleable solids in turbid water or in sewage containing settleable solids.

The fundamental principles of sedimentation are based upon the laws of nature, and the design of a settling basin should be of a type and character to allow the natural laws to function with the least possible interference. Occasionally some one advances a new scheme that is, or at least appears to be, in direct contradiction to the fundamental principles—which may be classed as a "new thought," or just a "wild idea." In order to obtain the opinions of others, considerable search has been made in recent articles in technical publications, texts on sewage treatment and in personal interviews with engineers interested in the subject. Some of the comments and opinions on the subject are quoted.

Baylis[1] states in an article published in 1928, concerning water purification, that not much improvement has been made in design of settling basins for many years.

Imhoff,[2] in an article the same year, begins with the following statement: "Ideas regarding the design of sewage settling basins for sewage treatment have often changed in the course of time. Even today there are no generally recognized rules."

Makepeace,[3] an English engineer, comments, "There seem to be many methods employed to bring about an uniformly good tank effluent. Without his reasons, it is very difficult to understand what was in the mind of the engineer in constructing certain types of tanks I have seen." Evidently Mr. Makepeace has seen some of the "wild idea" type.

Wolman, Donaldson and Enslow,[4] in a recent article reviewing progress of water treatment under the caption of sedimentation, state: "Improvements in this art are primarily resident in changes in containers and in the development of mechanical devices for the removal of accumulated materials."

Clifford[5] urges more care in design of sewage settling tanks, with due consideration of wide ranges in quantity and velocity of flows, avoidance of eddies and currents, dead spaces, short circuiting, etc. In other words, Clifford urges the need of sticking to the fundamental principles of sedimentation even in trying new thoughts.

* *Presented before the 1932 Spring Conference of the California Sewage Works Association, Yosemite Park, May 20 1932.*

Almost every week literature comes through the mail describing some new thought in sewage purification methods. Some describe improvements in mechanical devices, and others the various applications of nature's forces. Some claim greater efficiencies for settling tanks by horizontal flows, some by spiral flows and others by upward or downward flows. One of the latest pamphlets that has come to the author's attention is entitled *Lateral Sedimentation* by James W. Pearl of Chicago. The pamphlet is copyrighted and the process patented.

The March, 1932, issue of the SEWAGE WORKS JOURNAL contains an abstract from an article describing *Spiral Sedimentation Plant for Sewage Treatment*, by A. Hinderles.

This paper will, therefore, try to outline some of the fundamental principles of sewage sedimentation and briefly mention some of the "new thoughts." However, reference to "wild ideas" will be omitted, as there would naturally be considerable controversy on the author's opinion of what he might term "wild ideas"—some of which may not, after all, be so wild, but rather a new thought in the application of fundamental principles and a real advance in the art of sewage treatment.

Differences between Water and Sewage Sedimentation

The general fundamental principle of sedimentation, namely, the retarding of velocity of flow of a liquid for a certain period of time to permit the suspended contents heavier than the liquid to settle out of the line of flow, applies both to water and sewage clarification. The differences in method of applying the fundamental principle and in the design of the settling basins arise due to difference in character of the suspended settleable solids as generally found in water used for water supplies and sewage to be treated before ultimate disposal. Usually the major percentage of the settleable content in water is of inert minerals, of which a large part will settle more or less rapidly and will not decompose, gasify and return into the line of flow.

Sewage is of a more complex composition and varies greatly in contents and character due to source and character of the wastes, the freshness or condition as it reaches the point of treatment and many other variable factors. In addition to the settleable solids, the sewage carries floating material which should also be removed before being discharged into the place of ultimate disposal, or before further treatment by the secondary treatment processes or methods. The removal of floating materials is generally accomplished in the settling tanks by use of scum boards or baffles to collect the material and to remove same by hand or mechanical skimming devices.

Classes of Sewage Settling Basins

Sewage sedimentation basins may be classified into three groups according to the results to be obtained or the class of material to be removed, namely, grit chambers, primary tanks and secondary tanks. The material has been classified by Dr. Imhoff as "granular" sludge and "floccular" sludge. The term "granular" sludge is defined as the accumulation of suspended matter in which the independent particles settle with uniform velocity and independent of each other. In opposition, "floccular" sludge consists of particles which combine to form larger particles, with consequent increase in velocity of settling. Activated sludge and some chemical flocs are types of "floccular" sludge.

Grit Chambers

Grit chambers, as the name implies, are constructed for the purpose of removing the larger part of the heavier inert material of sewage, with the least accompanying amount of organic settleable matter. The velocity through the grit chamber is usually about one-half to one-third the velocity of flow in the incoming sewer, or should not be much less than one foot per second with a retention period of only a few minutes. Due to variation in rates of flow, it is difficult to maintain velocities that will not permit the deposition of considerable amounts of organic matters; except in large plants where multiple chambers are provided and with constant supervision to adjust the chambers with the varying flows. Hence most grit chambers in smaller installations become a nuisance and perhaps of very small value, especially if the sewage is not from a combined system of sewers.

Primary Tanks

Primary tanks are used for removing a large percentage of settleable solids as well as floating solids before disposal by dilution, irrigation and other methods of disposal, or further treatment by various oxidation processes. The material to be settled in raw sewage is comprised of a mixture of "granular" and "floccular" sludge. Imhoff[2] says that depth is not so important as surface area in primary tanks.

Secondary Tanks

Secondary tanks in general are used for the removal of "floccular" sludge in an activated-sludge effluent, and the clarification of sprinkling filter effluents. Skimming devices are seldom necessary in secondary tanks. In this case Imhoff recommends deep tanks and upward flows to obtain benefits of blanket filter action.

Factors to Be Considered in Tank Design

The first consideration in the design of a sedimentation tank is a study and a series of tests of rates of settling and the percentages of total settleable or suspended solids removed in given intervals of time. Chemical and physical tests can be made of raw sewage for primary or preliminary settling tanks, but, unfortunately, in most cases, no tests can be made on effluents from activated-sludge plants and sprinkling-filter plants until the plants are in operation and the final settling plants are constructed. While the general character of raw sewage may change, due to the addition of industrial wastes or other causes, the characteristics of the "floccular" sludge from an activated-sludge plant may change very rapidly in a short period of time. The efficiencies and results of both primary and secondary settling tanks in different plants vary sometimes quite widely. Townsend,[6] in a recent article on the settling characteristics of activated sludge, based upon tests and experience at the Milwaukee plant, states in conclusion: "It would be obviously difficult to set up definite basic settling-tank factors applicable to all sewages and the resulting sludge therefrom, and conservative design assumptions must be made in the instance of each specific sewage.... This problem embraces a study of two main factors, namely, the hydraulics and mechanics of a settling tank and its mechanical sludge-removing mechanism." In fact the conclusions derived from the results obtained in the operation of one plant are sometimes entirely opposite to the results from another plant. Then the question arises: Is it due to a difference in the sewage treated, a difference in design of the plant or perhaps in the methods of operation?

Settling tests of the average domestic sewage indicate that 80 to 90 per cent of the settleable solids may be removed by plain sedimentation. Furthermore, from 75 to 80 per cent of the settleable solids are deposited within the first hour to one and one-half hours, and the rate of settling of the remaining solids is usually very slow. Hence there is an economic limit in estimating retention periods.

The next consideration is the estimating of the permissible critical velocities. Fuller[7] states in his book that for horizontal-flow tanks, based on full displacement, the average velocities should range between 0.17 and 0.50 inch per second. Imhoff recommends not to exceed 2 inches per second at highest rate of flow. It is the author's view that the velocity should not be greater than one foot per minute, or about 0.2 inch per second for raw sewage settling; and about one-half foot per minute for activated-sludge settling tanks.

Having fixed the detention period and critical velocities, then comes the decision as to design in order actually to obtain these requirements. Involved in these considerations are: The shape (square or circular),

longitudinal or radial flow, horizontal or upward flow, depth, surface area, methods of inlets and outlets, determination of actual or displacement areas, quiescent and sludge storage zones. Good results have been obtained from various shapes and kinds of tanks, provided they have the required retention period and the velocity of flow does not exceed the critical value. The poor results from some tanks are caused by failure to still incoming velocities at the inlet end, thus losing a certain portion of the estimated retention period by jet velocities through small openings and the production of eddies and cross currents. Other causes of poor results are short circuiting or incorrect assumptions on the displacement of the liquid in the flowing-through zone, which means short retention periods and higher velocities.

The flow of a liquid will follow the line of least resistance, which is usually the shortest route between the inlet and outlet.

Baffles may eliminate dead spaces and increase displacement, but it is to be remembered that increasing the distance of flow, for the same flowing-through period, means increased velocity, and baffles may set up eddies and cross currents of a nature that will lessen the efficiency of the basin.

Contracted outlet openings will produce velocities near the outlet that will destroy a portion of the estimated effectiveness of the basin.

Added efficiencies in basins have been made by providing greater outlet weir lengths, or the lessening of the rate of overflow per unit length of weir. This may reduce short-circuiting and thus decrease actual overflow rates per square foot of tank area, reduce outlet eddies and reduce velocities across tank, or at least toward the outlet end.

An interesting test was made recently under the direction of Mr. A. M. Rawn, Asst. Chief Engineer of the Engineering Department of the Los Angeles County Sanitation District, on a rectangular raw-sewage settling tank equipped with Link-Belt sludge removal mechanism. The dimensions of the tank are 12.5 ft. × 50 ft. by 12 ft. deep. The tank was designed and baffled for longitudinal flow, with an outlet weir 12.5 ft. long. The flow was temporarily changed to across the tank by arranging an inlet 50 ft. long with an outlet weir 38 ft. long parallel to the long sides. The results indicated approximately 33 per cent added efficiency in the cross-flow over the long-flow in this particular case, with the sewage being treated at the Los Angeles County plant. This is a new thought, as it reverses the general idea that the ratio of length to width in such tanks should be 2, 3 or 4 to 1, with the direction of flow in the long dimension.

Another test on the effect of longer weirs was made by Anthony J. Fischer at the Peoria, Illinois, plant. The tests were made simultaneously in two tanks of the same dimensions, same rates of flow and same character of mixed liquor from the aeration tanks. One tank was equipped with a launder type of weir near the end of the tank, having a total overflow

length of 107 feet; and in the second tank the weir was extended along the side to provide a total overflow length of 221 feet.

The results of varying overflow rates per square foot of surface area are as follows:

	SUSPENDED SOLIDS	
Overflow Rate, Gals per Sq. Ft. Surface	P. p. m. Effluent Short Weir	P. p. m. Effluent Long Weir
580	16.5	10.2
935	39.0	20.3
1285	46.5	28.5

These tests not only show the importance of using low overflow rates for "floccular" sludge, but the importance of low velocities near the outlet.

Likewise, outlet weirs on end walls, particularly in secondary basins for settling activated-sludge floc, may produce wall currents that will raise floc that is well on its way toward the sludge removal zone.

Depth is not so important in flowing-through tanks for settling raw sewage, if such tanks are equipped with sludge removal mechanisms, or two-story tanks where sludge is stored in a separate chamber. Seven to ten feet depths are usually sufficient to provide proper displacement volume, quiescent and sludge accumulation zones. While it is true that greater depths tend to produce denser sludges, under average sewage conditions, it is questionable whether these results are of sufficient benefit to justify the extra costs of construction of deeper tanks.

Depths in secondary settling tanks are of more importance. The general practice now is to utilize some of the upward flow principles even in a square flowing-through type of tank, to gain the benefit of blanket filtration, which necessarily requires greater depths. Then it is advisable in most cases to provide several feet of sludge storage to gain the concentration effect of the sludge before removal.

Chemical Precipitation

Chemical precipitation to assist sedimentation was one of the early methods used in sewage and water treatment. It still is used widely in water purification, but fell into disuse as a part of sewage treatment a number of years ago due to cost of chemicals, the large amounts of sludge produced without any efficient or economical means of disposing of the sludge wastes, and by the advent of the more modern methods of sewage treatment by the biological processes, with better resulting effluents and in many cases cheaper operating expense. However, chemicals may prove of economical benefit in assisting in the sedimentation of activated-sludge effluents. Goudey[8] reports better sludge conditioning and settling by the use of lime in the experimental sewage treatment plant operated by the Los Angeles Water and Power Department.

The new sewage treatment plant under construction at Dearborn, Michigan, under the process patented and controlled by The Filtration Equipment Corporation, New York City, uses paper pulp, lime and ferric chloride to assist the rapidity and efficiency of the sedimentation part of the treatment process.

Ralph Stevenson, Research Engineer with the Great Western Electro Chemical Company of San Francisco, is advancing a new thought in sewage sedimentation and treatment by the addition of chlorinated clay in the settling basins, resulting in higher efficiencies in sedimentation and clarification as indicated in experimental tests.

The Miles Acid Process is one of the older attempts of chemical precipitation by the use of sulphurous or sulphuric acid; the early experiments being run about 1911.

With lowered costs of chemicals and more advanced methods of handling and disposing of sewage sludges, some modification of chemical precipitation may prove to be real assistance and advancement in sewage sedimentation and sewage treatment processes.

Mechanical Devices for Settling Tanks

One of the comparatively new thoughts or arts in sewage treatment has been the development of sludge-removal devices for removing continuously, or at fixed intervals, the sludge accumulation from sewage and water settling tanks. In general, most of the sludge-removing devices were originally designed for ore refining processes and certain industrial wastes, and while the general principles of sedimentation have been recognized, yet the refinements and improvements have been made to meet the requirements of a more complex and, in cases, almost constantly varying character of liquid and sludge to be settled and removed.

The advantage of mechanically removing floating materials from sewage settling tanks has been the incentive for improvements in scum-skimming devices. The characteristics of "floccular" sludge have also stressed the necessity of designing equipment that reduces the chances of cross currents and eddies by the equipment installation, and not to produce eddies by moving parts that will stir up the settled sludge.

Conclusions

In conclusion, it is the author's opinion that the three important thoughts, whether new or old, that must be kept in the foreground in the design of sewage sedimentation, are: First, a proper inlet design to still incoming velocities to as nearly as possible the desired settling velocity; second, to maintain low overflow rates; and third, to avoid increase of velocities, wall currents and eddies by the design of outlet weirs.

The proper design of inlet and outlet weirs adds a very little percentage of cost, as compared with the total costs. Low overflow rates mean the enlargement of surface area and the addition of considerable costs. The results shown by Fischer's tests at Peoria, Ill., would indicate that where funds or conditions would prevent obtaining the desirable overflow rates, some of the loss in efficiency may be compensated for by the proper outlet weir design; and the same may be true with more care in inlet designs. Again, however, the general fundamental principles involved are: the retarding of velocity to less than the critical velocity and the securing of a retention period of sufficient length of time to permit the settleable matter to travel downward out of the flow, or so-called overflow zone. The mechanics of the design are to provide the capacity for retention and the retardation of velocity. The hydraulic principles are that a liquid will tend to travel in the line of least resistance and a sudden stopping or the deflecting of a liquid from the line of travel means cross currents and eddies, which are conducive to poor results in a sewage-sedimentation tank. Thus baffling to prevent short circuiting may produce other defects that are of equal or a more serious nature, especially with "floccular" sludge, as the author can testify from an early experience in design of settling basins.

It is to be remembered, also, that solids will displace other solids, but that an incoming body of liquid does not readily and completely displace another portion of the liquid.

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New Thoughts on Sludge Digestion and Sludge Disposal*

BY R. F. GOUDEY

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The chief problem in sewage treatment is satisfactory disposition of sewage solids. Separate sludge digestion has been generally accepted as the panacea for the sludge problem. Design for digestion tanks has been fairly well standardized. It is well to realize that the goal of sludge digestion is the reduction of sewage solids into a sludge which can be dried on sand beds without nuisance. This advantage is of doubtful value when compared with the shortcomings of having a large volume of overflow liquor to dispose of, considerable gas to control and a very liquid sludge to dewater.

The accepted practice is to augment ordinary sand-drying beds with glass-covered beds or with sludge-storage tanks to hold eight months' sludge accumulation for good drying weather. Even in sunny California drying on open beds becomes difficult during certain times of the year. Many are the new thoughts which can be expressed in reference to sludge digestion and the dewatering of digested sludge, yet the real avenue of future research probably lies in the development of a more direct method of reducing raw sewage solids to dryness.

Sludge Digestion

An up-to-date digestion tank is one which holds 20 to 30 days' raw sludge accumulation, is covered to collect gas and is heated to 85° to 95° Fahrenheit. This will give about 50 per cent reduction of volatile solids and produce a sludge which can be dewatered in good weather on sand beds without nuisance.

New tanks not sufficiently seeded seem to pass through a foaming period, regardless of whether pH control is used, or whether the tanks are heated from the start. It is remarkable how even the most obstreperous tanks finally settle down and thereafter give no trouble.

In an endeavor to accelerate digestion, considerable attention has been paid to such mechanical and physical features as shapes of tanks, seeding of sludge, circulation of sludge and spraying of scum with supernatant liquor, but without noticeable success. For this reason we have directed our research along biochemical lines. Acceleration of digestion is not of prime importance. It is far more to the point to produce a sludge with a

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lower water content and with better dewatering characteristics. This can be done by paying attention to enzymes, catalysts and filamentous bacteria. For instance, a two-stage digestion, the first at a pH of 5.5 in the presence of iron and lipase followed by a second stage at a pH of 7.5 and in the presence of diastase, will, when conditioned with lime, give a low water content, break down amino acids and produce an easily dewatered sludge. The gas production during digestion will be increased. Some such process as this appears to be the logical outcome of our present work.

In this connection we have found that the agencies which bulk and debulk activated sludge also bulk and debulk fresh and digested sludges. Apparently the same types of filamentous bacteria found in bulked activated sludge are also present in digested sludge. It is probably safe to say that foaming in Imhoff tanks is comparable to bulking of activated sludge. Another observation of interest relates to a possible explanation of why alkalinity is reduced during sewage purification. We have found that this decrease, amounting to 7000 pounds per month at our plant, is practically equal to the increase of alkalinity in the digested sludge, added to the equivalent represented by the carbon content of gas, which totals 7500 pounds per month. It clearly points to a needed distinction between inorganic alkalinity normal to the sewage and what may be termed the organic alkalinity under change by bacterial action in the carbon cycle.

A number of difficulties have been experienced with the sludge-digestion process. A rather sad lesson was learned with thermophilic digestion. Theoretically it gives better digestion but from the practical standpoint the sludge is most difficult to dewater, breeds flies on drying and is odorous. Operators have found that the usual scum-removal devices are totally inadequate to remove long time accumulation of scum. The scum outlet openings should be large enough so that the operator can, every two years or so, rake out all scum. Making the roofs of digesters gas-tight appears to be difficult. Floating covers have given trouble from binding and leaking. Gas explosions have already exacted a toll. The most serious indictment against the separate sludge-digestion process is the problem of overflow liquor. When discharged into treatment works it adds to the oxygen demand and suspended solid loads, in addition to poisoning the process with its products of decomposition. The plan of drawing off digested sludge simultaneously with the introduction of fresh sludge, which we announced last year as a good method for eliminating completely the overflow liquor problem, still proves successful. However, no other plant has yet adopted such a plan. It does result in making the digested sludge about 2 per cent higher in water than the raw sludge. Conditioned sludge can be thickened and the clear water in such a case presents no problem in disposal.

Dewatering and Drying of Digested Sludge

The old method of dewatering sludge is to dry it on sand beds. There is now serious question as to whether this is the most convenient and cheapest method or the one of least nuisance. Operators experience untold trouble in trying to dry sludge during rainy periods or during times of frosty nights and high winds. Under such conditions it takes some thirty days to get the sludge down to 30 per cent water. When one takes into account the cost of glass-covered beds or storage tanks or even the cost of land, where it is valued at $5000 per acre or more, it becomes cheaper to adopt vacuum filtration of sludge. For these reasons we were the first municipality, two years ago, to initiate experiments on dewatering of digested sludge mechanically. Our work with Dorr, Oliver and Wright filters has included such items as various types of coagulants, admixtures of celite, paper, sawdust, straw, clay, etc., dilution with clear water and activated sludge, return of dried filtered sludge, addition of substances to inactivate enzymes, addition of catalysts, heating of sludge to 180° F. to further inactivate enzymes and speed up chemical reactions and, what is most important, various methods and degrees of mixing of chemicals. Digested sludge with 90 per cent to 94 per cent water can be filtered with proper conditioning to 65 per cent moisture at a chemical cost of $3.50 per million gallons of sewage treated.

Digested sludge conditioned with coagulants alone cannot be reduced to less than 82 per cent to 84 per cent water. Some admixtures have the effect of lowering the moisture content one or more per cent, but most of them have no effect so far as the original dry solids are concerned. It is well known that digested sludge at 90 per cent water once dried and then wetted again will take up moisture only to about 30 per cent, and dried sludge for this reason makes a good admixture. The secret of filtering digested sludge to get moisture contents of 55 per cent to 65 per cent is that of introducing reducing agents and catalysts in addition to the adding of coagulants and admixtures. Digested sludge at 65 per cent water can be dried in an oven at 300° F. temperature in 30 minutes, with no need of resorting to higher temperatures, which are the source of nuisance difficulties elsewhere.

It may be that digested sludge can be dewatered and dried in one operation, if preliminary studies with spray-drying equipment work out. In recent years a device which breaks up material to be dried into a fine mist which exposed a large area to a temperature of 500–600° F. for a very short duration has proved successful in dewatering mineral and food substances. By this method digested sludge without the addition of chemicals can be dried from 90 per cent to 10 per cent moisture at about the same cost as with vacuum filtration. With the thickening of sludge

this method deserves careful consideration. We are looking forward to an actual installation with a great deal of interest.

Dewatering and Drying of Fresh Sludge

Since sludge digestion accomplishes relatively so little we and others elsewhere are endeavoring to secure the benefits of digestion by more direct means. Already two cities, Winston-Salem and Dearborn, filter raw sludges heavily treated with chemicals but with no thought of fertilizer recovery. Experimentally, a number of cities during the past six months have been working on the filtration of raw sludge using other methods. We find that raw sludge is easier to condition and filter than digested sludge.

Although digested sludge on a dry solids basis requires 50 per cent more chemical conditioning than fresh sludge it happens that when reduced to a million gallon basis the amount of conditoning of raw sludge and digested sludge is identical. The raw sludge cake is thick, granular, except for fibers it normally contains, is soft, friable, has no objectionable odor and dries exposed to the atmosphere in about twenty-four hours. Filter rates are high, the filter cloth remains clean and there is no binding. We are aiming at 50 per cent to 55 per cent moisture in the cake and have no trouble in securing 65 per cent without the use of admixtures, heating or return of dry cake.

The patented Wright method of filtering raw sludge proved entirely satisfactory. The filter cake is tough, dries nicely and can be pulverized. The moisture of the cake by that process is about 70 per cent and it is obtained at about the same cost as by other methods.

The total fixed and operating costs for dewatering raw solids to dryness is about $6.50 per million gallons of sewage treated. While this is about the cost of dewatering and drying digested sludge, use of this method has the added advantage of eliminating digesters, overflow liquor and gas control. It also economizes on the amount of land required for a plant, greatly simplifies operation and, what is by far the most important item, conserves twice as much nitrogen as is possible with digested sludge.

Disposal of Sludge

The logical disposal of raw or digested sludge in California is as a fertilizer. Digested sludge dewatered and dried contains about fifty pounds of nitrogen per million gallons of sewage treated. This nitrogen at $0.17 a pound gives a theoretical value of $8.50 per million gallons of sewage treated, which is greater than the cost of conditioning, dewatering, drying and delivery.

Raw sludge cannot be used for a fertilizer unless it is first humidified. This can easily be done with the wet cake by exposing it to mold action, after which it can readily be drained. We have found that it is not neces-

sary to bother with pure cultures of mold, since ordinary exposure in the proper environment suffices. Raw sludge will develop a mold in two days, whereas digested sludge by itself will never develop it. We got the idea from the farmer's way of mixing paper with green manure and subjecting it to mold action, which makes the best of fertilizer, and worked out our method last January. We were gratified to note in *Water Works and Sewerage* for April, 1932, that molds were actually used in partially dewatered fresh sludge from open sand beds in Atlantic City. The mold method of stabilizing sewage solids to prevent subsequent burning is unquestionably a far more efficient method than the liquid procedure in digestion tanks. It takes less room, produces a material much easier to dry, and gives double the amount of nitrogen secured from digested sludge. According to its nitrogen content raw sludge made into a fertilizer is worth $17 per million gallons of sewage treated. It is for this reason that a very careful investigation is being made into all of its phases.

Spray drying of raw sludge appears feasible but it should stop at about 35 per cent water content in order that it also can be subjected to mold action.

The possibility of hauling 55 per cent digested sludge or humidified raw sludge from the plant to citrus orchards direct and render spreading service at a specified application of nitrogen per acre may eliminate the necessity to dry to 10 per cent moisture.

Probably the most remunerative scheme for disposal as fertilizer is the use of the dried sludge as a base for synthetic fertilizers. Synthetic nitrogens and rock phosphates and even urea can be mixed with the sludges to produce the highest types of fertilizers known and command the best prices. At Charlotte, North Carolina, we found a "built-up sludge" selling for $80 per million gallons of sewage treated. Atlantic City reports obtaining $90 per ton which is equivalent to $72 per million gallons of sewage treated.

Conclusion

Sludge digestion and disposal of sludge are the two questions in sewage treatment which are undergoing rapid evolution. Digestion methods will have to be greatly improved in order not to be supplanted by more direct means of preparing sludge for drying.

By far the most promising outlet for stabilized dried sludge is as a base for synthetic fertilizers, the revenue from which will more than defray the cost of production.

Development of Power from Sewage Sludge Gas*

BY W. B. WALRAVEN

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Introduction

In the course of the anaerobic digestion of sewage sludge, either in the lower compartment of an Imhoff tank or in a separate sludge-digestion tank, inflammable and explosive gases are evolved. Chemical analyses indicate and experience proves that the gas is a mixture of various gases ranging from highly inflammable methane to comparatively inert nitrogen. The composition of the mixture may vary from time to time, due to environmental changes to which the gas-producing organisms are subjected, but within narrow limits the mixture of gases has fairly definite characteristics. One of the most commonly known of these characteristics is that the mixture will burn when ignited under proper conditions. This being true, it is evident that the gas has the latent ability to produce heat, and it is easy to conceive that it may also produce useful power.

In the past few years several cities, in this country and abroad, have made serious attempts to utilize the power latent within the sludge gas. Some of these attempts were poorly conceived and have proved to be failures, while others are meeting with continued success. One may wonder why the experiment is successful in one place while it is a failure in another, but I believe that the answer lies in a proper understanding of the nature of the gas and of the mechanical devices required for the development of power from it. A study of the factors involved may disclose that in one community, and under certain conditions, a supply of the gas may have little or no monetary value, while in another the same amount of gas may be worth thousands of dollars annually, if properly utilized.

Sewage sludge at the sewage treatment plant of the Springfield Sanitary District, is digested within six separate digestion tanks, two of which are covered with floating steel gas domes. The volume of gas collected has been sufficiently large to cause the trustees and myself to wonder whether we should not try to develop power as is being done in other places. Soon after beginning the study of the problem, I found that it involved many factors, which are discussed in this paper.

Use for Power

Three direct-displacement air blowers of the Connersville type are provided at the Springfield plant for compressing air for the activated-sludge tanks. The largest is driven by a 200 hp. electric motor, the second

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by a 150 hp. motor and the smallest by a 100 hp. motor. In addition to these, there are twelve smaller motors ranging in size from 1/2 hp. up to 10 hp. capacity, and aggregating 75 horsepower. At least one of the Connersville blowers, usually the largest one, is running constantly. The twelve small motors operate pumps, clarifier mechanisms, etc., and, for the most part, run intermittently. Our records indicate that the blowers use about 9 kw. hr. for every 1 kw. hr. consumed by the auxiliary motors and the lighting system. For this reason attention was directed primarily toward a study of the power consumed by the blowers.

Blower Characteristics

Records of the electric input to the blower motors were kept over a period of several weeks, and observations taken on the pressure at the blower discharge. The most important characteristics were found to be as indicated in Table I.

TABLE I

BLOWER CHARACTERISTICS

No.	Capacity, C. f. m.	Motor Rating, Hp.	R. p. m.	Kw. Input to Motor	Cost per Hour	Bhp. at Blower Shaft	Cost per B. H. P. Hour	Pressure at Blower Discharge, Lb. per Sq. In.
1	2200	100	450	68	$0.72	84.6	$0.00850	7.1
2	3300	150	450	102	1.07	127.0	$0.00845	7.3
3	4500	200	600	141.7	1.50	175.5	$0.00855	7.56

Springfield enjoys a low rate for electric current, due largely to the well-managed municipal generating station. This operates with favorable joint economy with the water-works, and takes advantage of the cheap local coal deposits and an ample supply of condenser water. With these favorable factors combining to give us a low electric rate, we feel that our costs for compressing air are certainly not excessive, as may be seen from a study of the data in Table II.

TABLE II

COST OF OPERATING BLOWERS

Blower No.	Million Cu. Ft. per Day	Current Cost per Day	Cost per Million Cu. Ft.	Annual Cost of Current
1	3.2	$17.28	$5.40	$6,307
2	4.8	25.68	5.35	9,373
3	6.5	36.00	5.55	13,140

Our air plates are relatively new and therefore not badly clogged, but as time goes on we can expect clogging, with consequent increase in air pressure. When this happens, our current bill will rise almost in direct proportion to the increase in pressure. As a matter of fact, all three blower motors were designed to reach their rated capacity when the blower

discharge is 8.5 lb. per sq. inch. Table I shows that the motor on blower No. 3 is rated at 200 B. H. P., and that it now delivers 175.5 B. H. P. with the discharge pressure at 7.56 lb. per sq. inch. When the pressure becomes 8.5 lb., the B. H. P. should be 197.3, indicating that under present conditions the blower is operating quite close to the design specifications. At 8.5 lb. discharge pressure, the cost of current to operate this blower will be $14,774 per annum.

I do not wish to give the impression that we can or even hope to be able to develop sufficient energy from our gas to compress all the air required to run the aerators. On the contrary, we realize that the best that can be accomplished is to develop enough energy to make the project sound and feasible economically.

Air Requirements

The daily sewage flow at the Springfield plant averaged 7.5 million gallons for the year 1930. We have some flexibility in the selection of air quantities by changing blowers or by making use of the limited number of possible combinations, but we cannot vary the quantity of air delivered by any one blower, since we do not have variable speed motors. This inability to vary quantities is not considered as much of a handicap.

The capacity of the largest blower is sufficient to handle the average air requirements. There are times when we need more air than it can deliver, and likewise times when one of the smaller blowers can take care of the air requirements, but we find that our current bill is about the same as we would have to pay if the largest blower were running continuously.

Characteristics of Sludge Gas

Chemist C. C. Larson of the Springfield Sanitary District has made several analyses of the gas, the average of which indicate a probable heat content of about 672 B. t. u. per cubic foot. This value compares fairly well with the heat value of sludge gas produced elsewhere, although actually not as high as is found in many localities. As was stated above, only two of our six digestion tanks are equipped with gas domes. We pump all fresh sludge into these two covered digesters. They are kept full at all times, the daily accretions being automatically transferred by continuous displacement into the open tanks for more complete digestion.

It is evident that the sludge passing out of the covered tanks is not fully digested and that gasification continues in the open tanks. Certain experiments by others point conclusively to the fact that during the early stages of digestion the percentage of carbon dioxide generated is high and the percentage of methane relatively low, while during the latter stages of digestion the carbon dioxide percentage falls and the methane percentage rises.

For example, it is reported on page 123 of the March, 1931, number of *Municipal Sanitation*, that at ordinary digestion temperatures the methane content of the gas rose from 70.7 per cent at 15 days digestion to 75.6 per cent at 30 days. Therefore, if we cover two additional tanks, we should trap more gas and also find it has a higher B. t. u. value.

Since some engineers have questioned the advisability of using sludge gas in an internal combustion engine on account of the presence of hydrogen sulphide, I furnished a typical gas analysis to a number of manufacturers and technical experts asking whether such gas would prove to be a successful fuel. I altered Mr. Larson's analysis by giving the hydrogen sulphide content as 0.1 per cent, an amount greater than he has found to date. The answer of the Cooper-Bessemer Company is typical of those received from eight well-known gas-engine manufacturers. It reads as follows:

"There is no question but that our engines will operate successfully on gas similar to your analysis."

The following is an extract from a quotation made by the U. S. Bureau of Mines relative to hydrogen sulphide:

"From our tests it is evident that a sulphur content of 0.040% does no harm, that 0.151% sulphur does considerable harm and that 0.458% does very great harm. Just where to draw the line is hard to say. It would seem, however, that 0.100% would be a fair dead line. No doubt, a lower sulphur content is desirable, but it is probable that a sulphur content of 0.100% would cause no appreciable injury."

A letter from the industrial engineer of the American Gas Association reads in part as follows:

"One of our engineers has just suggested to me that the use of hot, raw producer gas and blast furnace gas in driving engines for all sorts of power uses, shows that the presence of sulphur in the gas has no detrimental effects. Similarly, Diesel engines are operated for years with crude oils containing high percentages of sulphur and do not show any special signs of wear."

The Superior Engine Company states that:

"The proportion of hydrogen sulphide mentioned by you, 1000 parts per million, would be of no consequence whatever in the operation of a gas engine."

The Bruce-Macbeth Engine Company reports in part as follows:

"It would appear that this gas is just as suitable for the operation of our engines as is natural gas, provided it is commercially clean and free from impurities such as dirt and tar."

"Fuel variations do not affect efficiency. Bruce-Macbeth engines operate on gas of any B. t. u. value from 125 to 3000 per cubic foot."

Amount of Gas

At present the volume of gas collected fluctuates between 30,000 and 65,000 cu. ft. per day, with an average of more than 40,000 cu. ft. per

day for the year. For a community as large as the Springfield Sanitary District, which has a population of 75,000, and with the digestion tanks receiving both primary and secondary tank sludge, this appears to be a low production, but it must be remembered that only two of the six digestion tanks are covered. It is my opinion that if we were to place gas covers on two additional tanks, and use the remaining two uncovered tanks for sludge storage only, we might safely figure upon trapping an average of 50,000 cu. ft. per day, with a possibility that the average may run up to 60,000. The exact amount is, of course, conjectural, and does not affect the discussions in this paper very materially. The quality of the gas would be changed somewhat, with a strong probability that the heat content per cubic foot would be raised materially.

Value of Gas as Heat

Two gas-fired furnaces were installed, one to heat the combined control and office building of the District, and the other to heat the hot-water circulating system which maintains the desired temperature within the digestion tanks.

Calculations show that our maximum heating requirements are about 28,000,000 B. t. u. per day, divided approximately as follows:

a.	Building Heat	7,500,000
b.	Sludge Heating	12,500,000
c.	Tank and Transmission Losses	8,000,000

No records nor calculations have been made to indicate the average daily heat requirements for the year, but I believe they would prove to be about 20,000,000 B. t. u. Our experience is that the gas has been sufficient to supply all the heat required except during very few days in sub-zero weather, and when the volume of gas drops with lower temperature in the digesters.

If our daily average requirements are 20,000,000 B. t. u., let us see what we save by supplying this heat with gas instead of burning coal. We buy coal containing 12,000 B. t. u. per pound for $4.25 a ton delivered. A well-designed, well-operated coal furnace may give 70 per cent thermal efficiency. Under those conditions we pay $0.253 for each 1,000,000 B. t. u. put into the water by the furnace.

If our heat requirements were just met by the gas supply, and if the gas-fired furnace gives 70 per cent thermal efficiency, 40,000 cu. ft. of sludge gas per day at 672 B. t. u. per cubic foot delivers heat into the hot water system valued at $4.76 per day or $1737 per annum. The above calculations lead to an interesting deduction, as follows:

A daily flow of 1000 cubic feet of sludge gas for a year, or a total of 365,000 cubic feet, is equal in heating value to ten tons of coal. To get the annual value

of sludge gas for heating purposes, multiply the daily flow in thousands by ten times the price of one ton of coal.

It is obvious that the use of this measuring stick must be limited to conditions similar to those cited above and that the value of the numerical coefficient ten (10) will vary with the B. t. u. content of the gas and of the coal. However, it gives an easy way to evaluate the annual value of any daily volume of gas, when it is burned instead of coal.

Value of Gas Used for Power

The true value of a supply of gas depends upon what can actually be done with it and upon what it costs to be without it. Besides being burned in a furnace, sludge gas may be used quite successfully, in an internal combustion engine and it is interesting to note how much power may be derived from it. There are several well-known manufacturers who will guarantee that their engines will produce at full load 1 brake horsepower hour at the power take-off when furnished with 10,000 B. t. u. of gas. These companies also state that they will guarantee this performance when the engines are using sludge gas similar to that produced in our plant.

Two of the largest manufacturers in the country have offered to put up a bond to guarantee that their engines, when using our sludge gas, will measure up to the above performance. Four others wrote into their specifications that they could equal or better that figure. I seriously doubt that the light weight high speed engines can even approach this efficiency, but in the gas booster fields, hundreds of gas engines, ranging from 165 up to 1000 horsepower capacity, develop 1 B. H. P. H. on ten cubic feet of natural gas of 1000 B. t. u.

The efficiency of a gas engine is near its peak at the rated power capacity, and drops off with a decrease in the ratio between actual load and rated load. The following table illustrates this variation:

TABLE III

POWER REQUIREMENTS UNDER VARYING LOADS

Ratio Actual to Rated Load	B. t. u. per B. H. P. H.*	Cu. Ft. Sludge Gas per B. H. P. H.**
1.20	9,600	14.28
1.10	9,750	14.51
1.00	10,000	14.88
0.90	10,400	15.48
0.80	10,800	16.07
0.70	11,300	16.81
0.60	12,000	17.86
0.50	13,000	19.34

* Brake, not indicated horsepower.

** At 672 B. t. u. per cu. ft.

The best known manufacturers of stationary gas engines are unanimous in advising against the permanent crowding of their engines above the rated loads in order to realize the higher thermal efficiencies. The engines are built to run practically continuously for many years and should be operated at about the rated capacity or slightly below, if the best results are to be obtained.

If we assume that an internal-combustion gas engine be direct-connected to a blower similar to our largest one, we can work out some interesting data. Table I shows that Blower No. 3 requires 175.5 B. H. P. H. delivered at the shaft.

With electric current at 1¢ per kw. hr., a blower similar to No. 3 would require $1.417 worth of current for one hour's operation, or $12,410 per annum. If it were driven by a 175 B. H. P. gas engine, it would use 14.88 × 175.5 equals 2611 cubic feet of gas per hour or 62,660 cubic feet per day. This amount of gas would save $12,410 in electric bills per annum, with current at 1.0¢ per kw. hr. This leads to another interesting deduction as follows:

A daily flow of 1000 cubic feet of sewage sludge gas for a year, or a total of 365,000 cubic feet, is equal in power value to the input of 20,000 kw. hr. of electric energy delivered to a motor. To get the annual value of sludge gas for power purposes, multiply the daily flow in thousands of cubic fee. by the cost of 20,000 kw. hr. of electricity.

As was said for the formula for determining the heating value of gas in comparison with coal, let me say that this formula is not given out as a precise rule, but it will nevertheless give a fairly accurate measure of the value of sludge gas when used in a modern gas engine. It is the means of computing the value of the power delivered by a gas engine, direct-connected to a Connersville Blower, in comparison with the cost of electric current capable of performing the same amount of work.

This enables us to evaluate any given volume of gas, whether used for heating purposes or for power development. Last year we paid slightly more than 1¢ per kw. hr. for electric current, and $4.25 per ton for coal. I am certain that with two additional gas domes we should be able to trap a minimum average of 50,000 cubic feet of gas per day, which indicates that we could cut $10,000 per annum from our electric bill. Our heating arrangements are such that we shall not require more heat than can be supplied by 40,000 cubic feet of gas per day which, according to the formula, is worth $1700 per annum as heat.

The difference between $10,000 and $1700 represents the gross annual saving by utilizing 50,000 cubic feet of gas daily as fuel for a combustion engine instead of burning it in a furnace. From this must be deducted the several operation and carrying charges in order to arrive at the saving which may be effected. A later discussion on the subject of heat re-

covery from a gas engine points out the possibility of a still greater annual saving.

Heat Balance

As a by-product of the development of power within an internal combustion engine, a large amount of waste heat may be recovered. The advisability of attempting its recovery depends upon the cost in comparison with the cost of providing an equally large and available supply by other means. In order to bring out some of the most important factors, I have prepared a heat balance table (Table IV) showing what becomes of the B. t. u. of gas when passing through a modern gas engine of the Price-Rathbun type, as sold by the Ingersoll-Rand Company.

TABLE IV

HEAT BALANCE FOR 175 B. H. P. ENGINE

Horsepower (Brake)	175
Cu. ft. of gas per hour at 672 B. t. u.	2,610
Cu. ft. of gas per day	62,500
B. t. u. available in 62,500 cu. ft. at 672	42,000,000
B. t. u. required by engine per hour	1,750,000
Heat going to work—25.3%	443,000
Heat going to cooling water—33.3%	583,000
Heat going to friction—4.4%	77,000
Heat to radiation—3%	52 500
Heat to exhaust—34%	594.500
Heat to work in 24 hours	10,632,000
Heat to cooling water in 24 hours	14,000,000
Heat to exhaust in 24 hours	14,250,000
Exhaust temperature	900° F.

The data in Table IV show that, of the heat originally present in the gas, about one-quarter is transformed into useful work, one-third goes to the cooling water and one-third to the exhaust. It is true that at loads under the rated load, the percentage of heat going to work drops and that going to cooling water and exhaust rises, but for the sake of study the above figures are satisfactory.

Cooling Water

For best operation the cooling water should reach the water jacket at about 90° F. and leave at not over 125°, with 120° preferred as a maximum. If 14,000,000 B. t. u. are to be absorbed in 24 hours with a water temperature differential of 30°, the circulation pumps must discharge 39 G. P. M. through the jacket continuously, with pressure and velocity high enough to insure that there be no "dead" spots or air pockets. Provision must also be made for getting rid of the heat absorbed so that the returning water will again be at 90° F.

With some engines, and when using proper thermostatic regulation, the water jacket temperature may be allowed to reach even as high as 150° F. At such a figure the water from the jacket would be very useful for heating the digestion tanks.

The efficiency of a hot-water circulation system is not known, but it is probably safe to figure that the water jacket of a 175 B. H. P. engine at full load will actually deliver 14,000,000 B. t. u. per 24 hours. The percentage of this heat delivered to the sludge is conjectural, depending largely upon the losses in transmission.

Exhaust Heaters

There are on the market certain heaters designed to recover the heat from the exhaust of internal combustion engines. They differ markedly from ordinary, fire-operated boilers and heaters because of the difference between the temperature of the exhaust gas and the temperature within the fire box of a coal or gas boiler. A good exhaust heater is not efficient when gas fired, nor can a good gas-fired boiler be used as an efficient exhaust heater, although under certain conditions a modified exhaust heater may be used successfully when supplied with heat from either source.

The efficiency of heat recovery in one of these exhaust heaters depends to a large extent upon the difference in the temperature of the exhaust gas and the water or steam within the heater. With the "Thimble Tube" type of heater as sold by the Edgemoor Iron Company, the B. t. u. recoverable per hour from the exhaust gases of an internal combustion engine may be calculated from the following formula:

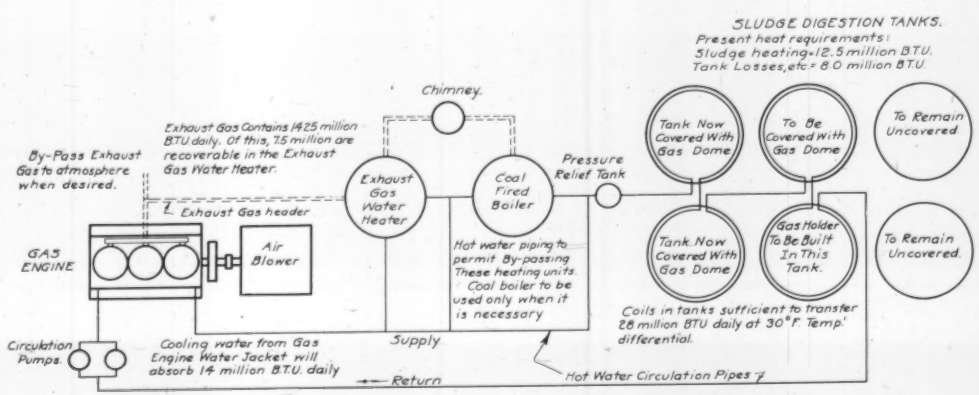
B. t. u. per hour = B. H. P. × C × D × 0.25, where "C" is equal to 12 for four-cycle engines, and equal to 20 for two-cycle engines, and where "D" is the difference in temperature of the gases, measured on the Fahrenheit scale.

In practice, the exhaust gas should leave the heater at not less than 300° F. If, as is the case with the 175 B. H. P., Ingersoll-Rand engine, the exhaust from the gas engine is at 900° F. then "D" in the formula becomes 600. From a four-cycle, 175 B. H. P. engine, one might expect to recover 175 × 12 × 600 × 0.25, equals 315,000 B. t. u. per hour or 7,560,000 B. t. u. per day.

Heating System Required

As mentioned previously, our maximum heating requirements are perhaps 28,000,000 B. t. u., with average requirements of 20,000,000 B. t. u. daily throughout the year. I have visualized a possible installation consisting of a series of units as follows:

DIAGRAM SHOWING MANNER OF UTILIZING WASTE HEAT FROM GAS ENGINE FOR HEATING SLUDGE DIGESTION TANKS.
Figures for B.T.U. recoverable from Exhaust Gas and from Water Jacket apply only to a 135 B.H.P. 4 cycle gas engine at full load.


SLUDGE DIGESTION TANKS.
Present heat requirements:
Sludge heating = 12.5 million B.T.U.
Tank Losses, etc. = 8.0 million B.T.U.
Chimney.
Exhaust Gas Contains 14.25 million B.T.U. daily. Of this, 7.5 million are recoverable in the Exhaust Gas Water Heater.
By-Pass Exhaust Gas to atmosphere when desired.
Exhaust Gas Water Heater
Coal Fired Boiler
Pressure Relief Tank
Tank Now Covered With Gas Dome
To Be Covered With Gas Dome
To Remain Uncovered
Exhaust Gas header
GAS ENGINE
Air Blower
Hot water piping to permit By-passing These heating units. Coal boiler to be used only when it is necessary
Tank Now Covered With Gas Dome
Gas Holder To Be Built In This Tank.
To Remain Uncovered.
Coils in tanks sufficient to transfer 28 million B.T.U. daily at 30° F. Temp. differential.
Circulation Pumps.
Cooling water from Gas Engine Water Jacket will absorb 14 million B.T.U. daily
Supply
Return
Hot Water Circulation Pipes

a. Gas engines, driving an air blower, with complete electric stand-by.

b. Circulating water pumps in duplicate, discharging into the engine water jacket and thence into an exhaust heater.

c. Exhaust heater with valves arranged to by-pass gas engine exhaust when desired, or to heat circulating water.

d. Coal fired boiler arranged so that the circulating water may be by-passed if desired, or heated above the temperature at which it leaves the exhaust heater.

e. Circulating water coils from furnace, around the digestion tanks, returning again to the circulation pumps.

In such a system the radiation surface of the coils within the digestion tanks would have to be sufficient to transfer 28,000,000 B. t. u. daily and permit the water to return to the engine at a temperature not to exceed 90° F., since it is vital that all of the water-jacket heat be dissipated.

The size of the pump required must be figured carefully, since the amount of heat lost at the tanks is a function of the rate of circulation as well as of the temperature differential. In general, it would be better to have the pump larger than really necessary, in order to be certain of safety.

If it proves possible to accomplish this program economically, the total value of the sludge gas will be increased beyond its value for producing power. In our particular case, the maximum *additional* annual saving would approach $1700. Such a system has interesting possibilities and I see no reason why it cannot be accomplished, especially in view of the fact that low grade heat is used to good advantage at the digestion tanks of a sewage treatment plant.

Factors Affecting Size and Type of Engine

It should be obvious that the present or future need for a certain engine size will be the governing factor in almost any installation. Granted, however, that there is a choice in the size of gas engine which may be used, the amount and uniformity of the gas production and the perfection of the stand-by service will affect the problem. Power requirements at Springfield are greater than can be supplied by any quantity of gas that we are ever likely to obtain and we shall always be users of auxiliary power. It appears that we should install a gas engine large enough to drive the unit using the most power, run the engine as long as the gas supply holds out, and then use the existing electrically driven unit. In this way we should get the most out of the gas. Due to the fluctuation in the production of gas, we should have to install a gas holder in order to supply a steady flow to the engine. If we did not have perfect stand-by service, we could not consider installing a unit which would use more than the minimum

supply. No doubt this has been at least partly the reason why many communities have not previously used sewage-sludge gas for power.

There are so many gas engines on the market that one should study quite carefully before choosing the type to buy. Perhaps the greatest field for gas engines is for booster service in the gas pipe-line industry. Almost invariably those used for this service are heavy, slow moving engines, built to run for thirty years at twenty-four hours a day, with a minimum of repairs or care. There are also higher speed, lighter weight, and less expensive engines, but they cannot be subjected to as long nor as hard service. The choice between types can be made intelligently only after a careful analysis of first cost and operating expenses.

Gas Holder

It is customary practice to construct a gas holder independent of all other structures and to cool the engine water jacket of a gas engine by recirculating the water within the stationary tank part of the holder, or through especially built cooling towers. This is an effective and inexpensive way to get rid of the heat, provided there is no economical use for it. At Springfield, I believe it would be possible to use one of our existing digestion tanks as the base and pit for the holder, thus eliminating the necessity for purchasing any portion of the holder other than the movable part, the vertical guides and the sway braces. The idea fits in perfectly with using the water within the engine water jacket to assist in heating the sludge in the digestion tanks. The digestion tank is 40 feet in internal diameter with the vertical section 21 ft. 8 in. high. In this should be placed a holder capable of furnishing a reserve supply of about 25,000 cubic feet, which should be amply sufficient to meet our requirements.

Installation and Operation Costs

No mention has been made of the cost of installing a system such as outlined above, nor of the annual expenses required to keep it in operation. This is because conditions at Springfield cannot be compared accurately with those pertaining elsewhere, and cost data, if given, might be misleading or wrongly interpreted.

We have made cost studies at Springfield on several possibilities, and are almost convinced that the idea is perfectly sound, and that it would prove to be an excellent investment. The whole question of cost is so intimately bound with those of local conditions and cost of electric current that it would be fatal to jump too hastily to a conclusion. That is to say, no one is qualified to pass competent opinion unless he has given study to the particular problem at hand.

Other Uses for Sludge Gas

It is just as easy for a gas engine to drive an electric generator as it is to drive an air blower. The use to which the power is put depends so much upon local circumstances that a broad discussion would be fruitless. The average generator is perhaps 92 per cent efficient. The efficiency of a motor will vary from 85 per cent up to 92 per cent depending upon conditions. If a gas engine is used to drive a generator, which in turn furnishes electric current to motors, we obtain a maximum of $0.92 \times 0.92 = 85$ per cent of the energy developed by the gas engine. In many instances it might be better to develop electric power than to drive the mechanical units directly by means of the gas engine, but where conditions are favorable, it appears better economy to have a direct connection between the engine and the blower, or other device.

It is very interesting to note in this connection that at Birmingham, England, gas engines totalling 950 brake horsepower, and burning sewage sludge gas, are now being used to develop electric current. They have proved so successful during three years of operation that the Sewerage Board has drawn plans for a new development, requiring 650 additional horsepower.

There are a few American installations in which sludge gas is used as power in engines driving pumps, although none of such proportions as those in Birmingham. There is no inherent reason why gas engines may not be used for many other purposes too numerous to catalog here; and by the time this article is published, we may hear of some important installation in which a gas engine is used to drive a mechanical aerator.

Much has been written concerning the sale of sludge gas for heating and illuminating purposes, particularly the fine article by W. H. Fulweiler in the July, 1930, issue of THIS JOURNAL. However, this phase of sludge gas development does not appear practicable to us in Springfield, so I shall pass the matter with no further comments.

Commercial Development of Electric Power

Where manufacturing establishments are located near natural gas lines, there have been many installations in which electric power is generated by gas engines. It would perhaps be interesting to record some average figures for the cost of the current so generated. The following table gives average switchboard costs per kw. hr., applicable to conditions prevailing in the Middle West.

From the table it may be seen that a manufacturing concern can afford to pay 35¢ per 1000 cubic feet of natural gas and still be able to put 1 kw. hr. on the board for 1¢. It is also apparent that at 35¢ per 1000 cu. ft., the cost of the gas is more than all other costs.

TABLE V

COSTS PER KW. HR. DELIVERED BY GAS ENGINE-DRIVEN GENERATOR

Price of Gas per 1000 Cu. Ft.*	Cost of Gas per Kw. Hr.	Other Costs per Kw. Hr.	Total Cost per Kw. Hr.
15	$0.0023	$0.0045	$0.0068
20	0.0030	0.0045	0.0075
25	0.0038	0.0045	0.0083
30	0.0045	0.0045	0.0090
35	0.0053	0.0045	0.0098
40	0.0060	0.0045	0.0105

* Using natural gas with B. t. u. ranging from 965 to 1020 per cu. ft.

For this tabulation, the "Other Costs" were figured on the basis of

Load factor at 80%;
Direct labor and repairs at $1.00 per B. H. P. per annum;
Lubricating oil at 1 gallon per 2000 B. H. P. H.;
Interest at 6 per cent;
Depreciation and amortization at 8 per cent.

Suppose the natural gas cost nothing. What would the cost of electric current be? It occurs to me that we are in a somewhat similar position, in that we have the gas at our door and all we have to spend is for the "other costs." I do not recommend that any one adopt my figures for the cost of developing electric power because they might not apply to all conditions, but they do represent the experience of a wide practice.

Conclusion

To me, the most enlightening part of the problem was the realization of its complexity. As engineers, we understand that sewage sludge gas contains power, but the efficient utilization of its latent possibilities requires a careful analysis of conditions existing at each plant, and recommendations which give consideration to problems in mechanical as well as sanitary engineering.

I am thoroughly convinced that in many instances cities and sanitary districts are overlooking a valuable source of energy by using the sludge gas for heating purposes instead of as fuel within an internal combustion engine. What the future may bring I do not profess to know, but I look forward to a more general development of power from this source.

Effect of Coagulants on Sludge Digestion*

BY WILLEM RUDOLFS, W. H. BAUMGARTNER AND L. R. SETTER

Chief, Research Assistant and Assistant Dept. Sewage Research

The use of coagulants as an auxiliary in sewage treatment, either for the coagulation and precipitation of finely divided material and colloidal matter in raw sewage before sedimentation, or as an aid in settling finely divided materials coming from settling tanks or sprinkling filters, is slowly forging ahead. Coagulants as an aid in the activated-sludge process have been used and possibly may be used more when the process is still better understood. In the several cases mentioned the coagulants find their way ultimately to the digestion tanks in conjunction with the sludge to be stabilized. The effect of certain iron compounds, used as coagulants, on digestion and gas production has received some attention[1,2,3] but little is known about other coagulants that can be used. Some studies have been made on the effect of alum-sludge obtained from water treatment plants but the effect of coagulants which at the same time may serve for reaction adjustment has not been shown. Part of the work reported in this paper was done under a fellowship grant from the National Aluminate Corporation.

Two general types of experiments were conducted:

1. Addition of coagulants to mixtures of fresh solids and ripe sludge.
2. Addition of coagulants to raw sewage using the settled fresh solids after mixing with ripe sludge.

The coagulants used were dry sodium aluminate ($Na_2Al_2O_4$), sodium aluminate solution containing free NaOH, Feralum, Feralum sulphate, alum, ferric chloride and mixtures of some of the coagulants.

Partially Seeded Material

It was thought that some of the coagulants would have a decided effect upon the reaction of the mixtures and for that reason mixtures of fresh solids and ripe sludge were prepared on a volatile matter basis of one part of ripe sludge to 4 parts of fresh solids. Coagulants were added on the basis of the suspended solids in the raw sewage, amounting to 5 p. p. m. coagulant with a sewage containing 200 p. p. m. suspended solids. A condensed summary of the results obtained after 70 days of incubation (at 72° F.) when gas production of the control mixtures had practically stopped is given in Table I. Ferric chloride and Feralum sulphate produced less gas than the control, while the alkaline material sodium aluminate, both in dry form and solution, produced more gas.

* *Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J. Dept. Sewage Research.*

The mixture to which sodium aluminate solution was added (which contained some free sodium hydroxide) produced in 55 days the same quantity of gas per gram of volatile matter added as the control mixture in 70 days, and the mixture to which dry sodium aluminate was added (containing no free alkali) produced a similar quantity in 50 days. The peaks of gas production correspond with these differences, except that they came 15 and 20 days earlier.

TABLE I

EFFECT OF COAGULANTS ON PARTIALLY SEEDED MATERIAL (DIGESTION TIME 70 DAYS)

Treatment	Solids Reduction, %	Vol. Matter Destroyed, %	Gas per Gm. Vol. Matter Added, Cc.	pH Initial	pH End
None	29.0	41.5	650	6.7	7.5
Sod. Aluminate (Sol.)	37.5	45.5	690	6.9	7.7
Sod. Aluminate (Dry)	34.5	46.7	735	6.8	7.8
$Fe_2Al_2(SO_4)_6$	35.5	46.4	595	6.1	7.6
$FeCl_3$ (49%)	34.5	44.7	565	6.3	7.7

The percentage volatile matter destroyed was in all cases somewhat greater for sludges receiving alum compounds than in the control. Although the mixtures receiving sodium aluminates were slightly alkaline,

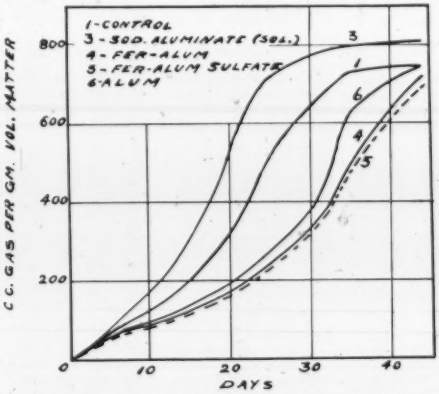


FIG. 1.—Effect of Coagulants on Total Gas Production.

as shown by a slight increase in the pH values of the mixtures when the salts were added, the increase in pH values was so small that the effect could not be entirely attributed to reaction adjustment. It seemed

possible that either the aluminum compounds acted as a biological catalyser or were capable of exerting a better buffer action. Offhand it would be expected that the buffering action of the iron salts would be similar, unless the anion of the iron salts had a greater retarding effect so that the effect of the cation was obscured.

Properly Seeded Mixtures

Fresh solids and ripe sludge were mixed on a volatile matter basis of 2:1. Coagulants were added at a rate of 5 p. p. m. based upon a sewage

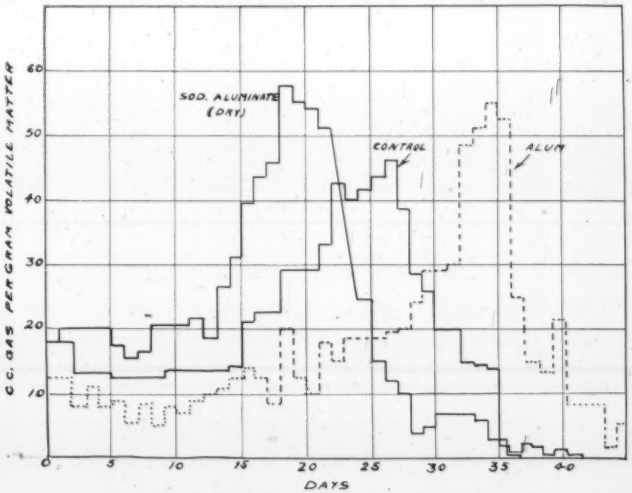


FIG. 2.—Comparison of Daily Gas Production of Different Mixtures.

containing 200 p. p. m. suspended solids. The cumulative gas production per gram volatile matter added is shown in Fig. 1. The results of the two sodium aluminate mixtures were practically identical in so far as total gas production was concerned. These two mixtures produced more gas than any of the others and the maximum production came earlier, with the result that the digestion time was shorter. The difference in time required for maximum gas production is well illustrated in Figure 2, where the daily gas production per gram volatile matter added is plotted. The peak of gas production in the mixtures treated with sodium aluminate came 5 to 9 days earlier than in the control, while the peak of gas produc-

tion from the mixture receiving alum came 7 to 10 days later. After 25 days of incubation (80° F.), when 90% of the total gas had been produced by the mixtures treated with sodium aluminate, less than 70% had been produced by the control and less than 40% by the other mixture. The relation between the different mixtures, together with the days required to reach the gas peak and the total digestion time is shown in Table II. The total digestion time was materially shorter for the mixtures treated with the alkaline salts (sodium aluminate) than the control and considerably longer for the mixtures treated with the "acid" salts. The reduction in digestion time and increase in gas production is of even greater interest if the composition of the gas is not changed. Analyses of all the gas produced are summarized in Table III. It is evident from the results that the "alkaline" salts which produced more gas did not stimulate CO_2 production, whereas the "acid" salts stimulated CO_2 production materially. For instance, where the control produced 87 cc. CO_2 per gram of volatile matter the mixture to which alum was added produced 125 cc. CO_2 per gram volatile matter.

TABLE II

GAS PRODUCTION OF VARIOUS TREATED MIXTURES AFTER 25 DAYS

Treatment	Cc. Gas per Gm. Vol. Mat.	% of Total Gas	Gas Peak, Days	Digestion Time, Days
None	510	69	24–27	35–36
Sod. Aluminate (Dry)	722	91	18–19	28
Sod. Aluminate (Sol.)	715	89	18–19	28
Feralum	233	33	34–35	44–45
Feralum Sulphate	241	35	34–35	44–45
Alum	281	38	34–36	41

TABLE III

SUMMARY OF GAS ANALYSES

Treatment	Total Gas per Gm. Vol. Matter, Cc.	CO_2, %	Combustible, %	Increase or Decrease Over Control		
				Total, %	CO_2, %	Combust.
None	741	11.8	73.7	...	..	..
Sod. Aluminate (Dry)	795	13.1	85.2	6.6	16.5	19.2
Sod. Aluminate (Sol.)	808	10.1	71.5	8.1	−6.0	1.3
Feralum	717	18.0	80.5	−3.2	32.6	5.3
Feralum Sulphate	688	16.7	81.5	−7.2	25.0	3.5
Alum	732	17.1	78.7	−1.3	30.5	5.3

Solids Treated at Plant

While plant experiments were in progress to determine the coagulation and flocculation effects of the different salts on suspended sewage solids, quantities of fresh solids were collected for digestion experiments. The

quantities of salts to be added for good coagulation were in some cases so large that the procedure was uneconomical. Sodium aluminate used alone gave comparatively poor results, while ferric chloride produced good results. A mixture of ferric chloride and sodium aluminate when added to the sewage in proportion of 20 p. p. m. $FeCl_3$ and 7 p. p. m. $Na_2Al_2O_4$ as a dry salt seemed to be as efficient in clarifying the sewage as 40 p. p. m. of $FeCl_3$ alone. With the amount of finely divided material present in the Plainfield sewage the latter figure was the lowest that would cause persistently marked clarification. Fresh solids were collected during treatment with those salts which seemed promising for clarification. Untreated fresh solids were collected prior to and after treatment with the different salts. The solids and ash contents of the materials used for the digestion were as follows:

No.		Solids, %	Ash, %	pH
A	Fresh Solids	4.28	24.7	5.4
B	Fresh Solids Treated with $FeCl_3$	5.50	25.0	5.4
C	Fresh Solids	4.14	24.3	5.3
D	Fresh Solids Treated with $Na_2Al_2O_4$ and $FeCl_3$	5.57	25.4	5.4
E	Ripe Sludge	5.61	49.4	7.5
1	Mixture Untreated	4.67	35.6	6.6
2	Mixture $FeCl_3$ Treated	5.58	35.7	6.7
3	Mixture Untreated	4.90	35.0	6.6
4	Mixture with $Na_2Al_2O_4$ and $FeCl_3$	5.56	34.5	6.7

Mixtures 1 and 2 were incubated at 72° F. and mixtures 3 and 4 at 80° F. Earlier experiments had indicated that fresh solids treated with $FeCl_3$ produced less gas but that the digestion time was considerably reduced. It was thought possible to correlate the digestion time of sludge so treated with the temperature of incubation. If a stable sludge could be produced in a shorter time with the addition of $FeCl_3$ as a coagulant, it may not be necessary to heat the tanks to the same degree. In other words $FeCl_3$ treated fresh solids require less time for digestion at lower temperatures than untreated material, for equal amounts of sludge, or if more sludge is produced, no more time is required for the additional quantities of sludge to be handled.

Cumulative gas production per gram of volatile matter added for the four different mixtures is shown in Figure 3. The difference in total gas production between the $FeCl_3$ treated fresh solids and the control is considerable. Gas production for practical purposes was completed in 35 days for the untreated mixture while a period of only 25 days was required for the treated mixture. However, there was no difference in gas production or digestion time required between the $Na_2Al_2O_4$ plus $FeCl_3$ treated material and its control. Table IV is a summary of the total volatile matter reduction and gas production. It is of interest to note

that the amounts of gas per gram of volatile matter destroyed were similar in all cases. The differences between the gas production of $FeCl_3$ treated mixture and the other mixtures is due to less destruction of volatile matter, or as previously pointed out[4] to the possible temporary locking up of substances which are capable of gas production. Since the fatty substances are producing most of the gas it could be assumed that some of these substances were rendered inactive. Preliminary investigations show, however, that the ether-extract content of treated and untreated digested materials does not differ sufficiently to account for the difference in gas production. It is of interest to note that by the addition of sodium aluminate to the $FeCl_3$ used as a coagulant the depressing effect was overcome.

TABLE IV

SOLIDS REDUCTION AND GAS PRODUCTION FROM TREATED FRESH SOLIDS

No.	Treatment	Incubation Temp., ° F.	Vol. Matter Red., %	Gas per Gm. Vol. Mat., %	Gas per Gm. Vol. Mat. Destroyed, Cc.	Gas Peak, Days	Digestion Time, Days	pH End
1	None	72	39.0	740	918	26	35	7.4
2	$FeCl_3$	72	25.4	480	930	16	25	7.4
3	None	80	37.2	701	925	12	27	7.4
4	$Na_2Al_2O_4 + FeCl_3$	80	38.0	695	935	12	27	7.4

Effect on Bacteria

The possible toxic effects of $FeCl_3$ on bacteria in digestion mixtures is of interest in connection with the decrease in gas production. Some of the preliminary experiments showed the following:

Treatment	Amount in P. p. m.	Millions of Organisms per Cc.
Control	0	13.2
$FeCl_3$	5	15.5
$FeCl_3$	10	3.6
$FeCl_3$	20	0.24
$Na_2Al_2O_4$	5	14.6
$Na_2Al_2O_4$	10	15.2
$Na_2Al_2O_4$	20	13.0

The indication is that with larger quantities of $FeCl_3$ the numbers of microörganisms are affected, while this was not the case with the $Na_2Al_2O_4$. It would, of course, be of far more interest to know which groups of microorganisms are first or mainly affected.

Effect on Odor Production

When different coagulants are added to sewage it is of general interest to know the effect of such additions on odors. Experiments have shown that about 95 per cent of the odor produced during digestion is caused by

hydrogen sulphide. While the different mixtures were digesting the H_2S evolved was trapped and measured. With the same quantities of coagulants added the results were as follows:

Treatment	Mg. H_2S
Control	4.02
$FeCl_3$	0.91
Sodium Aluminate (Dry)	4.16
Sodium Aluminate (Sol.)	3.58
Feralum	9.36
Feralum Sulphate	13.73
Alum	21.54

The $FeCl_3$ reduced hydrogen sulphide evolution, whereas the sodium aluminates had but little, if any, effect, but the alums produced considerable more than the control.

Effect on Reaction

Various amounts of sodium aluminate and lime were added to mixtures of fresh solids and ripe sludge to determine the relative effects on the reaction of the mixtures, in view of utilizing dry sodium aluminate for

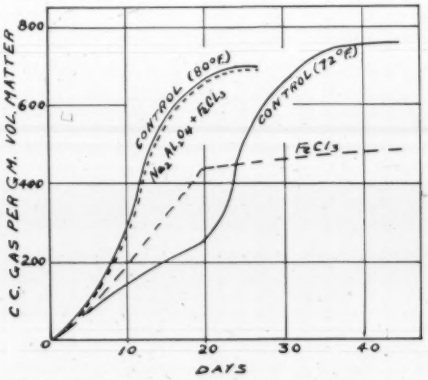


Fig. 3.—Cumulative Gas Production from Plant Treated Solids (1 and 2 at 72° F., 3 and 4 at 80° F.).

reaction control. The results showed that sodium aluminate compares favorably with hydrated lime for reaction control. It acts as a better buffer than lime, is easier to handle, and did not produce caking. A series of experiments conducted with seeded fresh solids, to portions of which

sodium aluminate was added and to other portions hydrated lime, showed that except with higher quantities of chemical added, gas production from mixtures with sodium aluminate was higher than from mixtures treated with lime. Additions of 0.4 gm. $Na_2Al_2O_4$ per liter of sludge appeared to be best. The total gas produced per gram of volatile matter after digestion for 30 days was as follows: Control 833 cc.; 0.4 gm. $Na_2Al_2O_4$, 868 cc.; 0.4 gm. lime 784 cc. All other mixtures were in the same relation. The time required for reaching the peak of gas production with sodium aluminate was from 1 to 2 days less than with the lime mixture and from 2 to 3 days less than with the control.

Discussion

Coagulants used for clarification of raw sewage to produce a better effluent, or to reduce the load on trickling filters, are applied to remove from the liquid finely divided suspended solids and probably some colloidal substances. The salts used can be grouped together according to the effects produced on the digestion processes. One group seems to stimulate digestion and gas production, while the other group retards digestion and stimulates carbon dioxide and hydrogen sulphide production. The "alkaline" salts fall in the first group and the "acid" salts (with the exception of $FeCl_3$, which did not stimulate H_2S production) in the second. Hydrogen sulphide production increased with the salts containing sulphates. The latter may be assumed to be the source of the additional odor. It is possible that increased CO_2 production is also a factor. During the first stage of digestion (acid stage) CO_2 is normally produced in greater quantities than during the second or alkaline stage of digestion. The addition of acid salts would retard alkaline digestion somewhat, with the result that more CO_2 is produced during the "acid" digestion stage. The result of gas analyses bears this out, when the first part of the digestion period, before the gas peak was reached, is compared with the second part of the digestion period. The percentage of CO_2 in the gas was as follows:

No.	Treatment	First Stage	Second Stage
1	None	16.0	11.0
2	Sodium Aluminate (dry)	10.1	11.1
3	Sodium Aluminate (sol)	8.5	11.1
4	Feralum	23.0	14.5
5	Feralum Sulphate	22.2	13.6
6	Alum	20.0	10.2

During the first stage of digestion CO_2 production was lower from the mixtures treated with alkaline salts than the control, whereas additions of acid salts produced more CO_2. Most of the odor production occurred during the first stage of digestion, when the percentage of CO_2 was greatest.

Sodium aluminate solution contains some free sodium hydroxide. This

free alkali served as an aid in reaction adjustment and, in forming sodium carbonate, reduced the CO_2 evolution. The general result was a somewhat greater gas production, of greater heat value, in less time. It appears, therefore, that the material may be considerably better for reaction control than hydrated lime, which as a rule decreases the total gas production. It has the added advantage that it does not cause caking of the sludge and is easier to handle.

Sodium aluminate added to raw sewage does not cause rapid flocculation, but a mixture of sodium aluminate and ferric chloride produced marked clarification with less chemicals. The retarding effect on digestion caused by the ferric chloride was counterbalanced by the stimulating effect of the sodium aluminate. These results indicate that sodium aluminate affects the physico-chemical reactions taking place during coagulation and at the same time makes the medium favorable for microorganisms. The few results obtained on the numbers of organisms present when sodium aluminate is added would seem to show that the numbers of organisms are not necessarily increased.

Summary

Experiments were conducted to determine the effect of different coagulants on digestion of improperly and properly seeded fresh solids. Solids were treated in the laboratory and collected after treatment at the plant. Sodium aluminate added to raw sewage did not cause rapid flocculation but a mixture of sodium aluminate and ferric chloride was better than $FeCl_3$ alone, requiring less chemicals. Alum compounds retarded digestion and produced less gas. Sodium aluminate appeared to have advantage in reaction control; it is easier to handle and better than hydrated lime, does not cause caking of the sludge and stimulates the digestion processes, producing more gas. Sodium aluminate, with and without free alkali, and $FeCl_3$ did not produce more odor, but alum, Feralum and Feralum sulphate increased H_2S evolution considerably. The latter compounds also increased CO_2 production. Ferric chloride reduced the number of organisms whereas sodium aluminate did not.

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Sewage Works Operation

Sewage Disposal Trends in the New York City Region*

By George W. Fuller

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I am gratified to present a paper before these two associations who have done so much to advance efficient sewage disposal in legislative and administrative aspects as well as in design, construction and operation.

I shall speak today of what has been done and is planned along these lines in the New York City region, with particular reference to the gradual trend, in the face of difficulties, toward district or coöperative undertakings.

This region, as described in the reports of the Committee on Regional Planning of New York and its Environs (now the New York Regional Planning Association), embraces an area of 5528 square miles, in New York, New Jersey and Connecticut, and has a total population of over 10,000,000. Twenty-two counties and 436 municipalities are included. Of the total population, over 2,000,000 persons are in northern New Jersey, nearly 1,000,000 in Connecticut and the balance in New York State.

As yet, no plan for dealing with pollution comprehensively by a centralized interstate authority has been adopted, although recently a treaty commission formed for the purpose has reported a proposed form of tri-state compact. Such district or joint undertakings as have been carried out lie entirely within the boundaries of one or another of the states, and even in those instances the development of workable plans for financing and administering the projects has been beset by legislative and other difficulties.

The Region embraces a great diversity of pollution conditions and remedial needs. The waters affected include the open seaboard, Long Island Sound, large estuaries and their branches, large and small tidal streams and small upland streams. This diversity, coupled with differences in state regulatory legislation, has led to a wide variety of remedial steps and administrative arrangements. The earliest projects were individual and were intended for local relief, where for one reason or another pollution was particularly objectionable, principally at points on small streams. From this starting point it is interesting to trace the halting but marked trend toward district or joint-authority undertakings, constantly becoming

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more comprehensive in scope, as well as in the growth of public opinion in support of a general cleaning up of the waters of the Region.

Summary of Accomplishments Prior to 1898

The most constructive developments in pollution control in New York City date from the merging of the five constituent boroughs into Greater New York in 1898. At that time the local sewer departments were largely occupied in rebuilding sewers and drains, many of which were laid before the Civil War. In the old City of New York, now the Borough of Manhattan, the outlets terminated at the bulkhead line and conditions in the slips were offensive. Rudolph Hering in 1888 recommended that these outlets be extended from the bulkhead to the pierhead line, an undertaking which required nearly 20 years for completion.

During the nineties there were very few small scattered treatment plants in the New York Region. They were mostly of the chemical precipitation type and several were of a proprietary nature. Along the seashore there were such plants at Coney Island, Sheepshead Bay and Long Branch, as well as at White Plains, New York, and East Orange, New Jersey. The only land treatment was at the filter beds at Summit, New Jersey.

The prevailing method of sewage disposal, with the exception of these small scattered plants, was that of dilution in the nearest watercourse by the most convenient arrangements. Available diluting water in many localities seemed ample and there was but little complaint in and around New York Harbor. Although the lower Passaic River until 1895 served as a source of water supply for Jersey City and until 1892 for Newark rapid growth of the industrial cities of Paterson and Passaic quickly changed this stream into a black, foul-smelling channel, differing but little from an open sewer in very dry seasons.

State boards of health gave little concern to sewage treatment although state sewerage commissions were soon to become active in New Jersey and Connecticut. Federal activities as to sewage disposal were, and still are, very meager because jurisdiction is limited to obstruction of navigable water. Since 1888 the War Department has had an officer of the Navy designated as Supervisor of the Harbor so as to control the discharge and deposit of sludge, dredgings and other solid matters reaching the tidal waters of New York Harbor or tributary waters. In general, the period up to 1898 was one of little accomplishment in the Region's sewage disposal problems.

Developments from 1899 to 1919

The period from 1899 to 1919 is conspicuous for the rise of state jurisdiction to a more adequate plane. It was accomplished by supplementing the common law with statute laws, aimed to control the disposal of sewage,

and the setting up of state departments of health or similar agencies with such jurisdiction. Technical staffs for some time were very meager.

The period was marked also by substantial progress in the formation of sewerage districts to meet the needs of different types and combinations of municipalities and the Constitution of the states under consideration.

Types of treatment plants changed markedly and during this period there came into existence many septic tanks, contact beds, sprinkling filters and, later, Imhoff tanks. Some plain sedimentation tanks were also developed. Improvements were likewise made in facilities for discharging sewage into watercourses through submerged multiple outlets.

There is little need of dwelling upon these historical steps. The state of New Jersey adopted legislation permitting some ten cities and towns adjoining Summit and South Orange to build an outfall sewer for the discharge of sewage into the Kill von Kull. This undertaking was effected under the provisions of a law permitting two or more municipalities to construct joint works. Under the New Jersey Constitution, as interpreted by the state courts, districts may not issue securities of their own and it is necessary for contractual relations to be established by interested municipalities, each of which is obliged to provide its own pro-rata share of funds needed.

The Passaic Valley sewerage project was intended to take definite form as a result of legislation passed in 1902. Litigation over the constitutionality of the act occupied several years and the law under which the constructing commission came into existence was adopted in 1907. A definite project reported upon in 1908 encountered opposition from a number of communities expected to participate in the joint undertaking and also from the State of New York and the Federal Government as to the discharge of settled sewage through multiple outlets at the bottom of New York Harbor near Robbins Reef Light. In 1911 contracts were made with 15 municipalities and definite steps toward completion of design and placing works under construction were effected. Supplementary contracts were necessary to provide additional funds due largely to the increase in prices, so that it was not until August, 1924, that these works were placed in service. The Passaic trunk sewer is now serving all or parts of 22 communities.

A trunk sewer for the Bronx Valley was agitated as early as 1895 but it was not until 1905 that legislation was enacted to provide for correcting the pollution of this small stream through Westchester County and the upper portion of New York City. It was proposed to divert the flow of the trunk sewer through a tunnel to the westward into the Hudson River in Yonkers. Various objections were made by neighboring property owners, by the city of New York through its Metropolitan Sewerage Commission and also by the United States Government. The project was built in 1909–11.

Sewer districts were established by legislation in New York, in New Jersey and Connecticut, for one or more portions of a municipality and for projects serving parts or all of two or more municipalities.

The pollution of New York Harbor has been investigated by many commissions, beginning in 1903, following the passage of a Passaic Valley Trunk Sewer Act. The New York State Legislature created the New York Bay Pollution Commission which was succeeded in 1906 by the Metropolitan Sewerage Commission which undertook a comprehensive, through-going investigation of local conditions and made its final report in 1914. This report dealt with main drainage and the collection and disposal of the sewage of the City of Greater New York as well as an administrative program for its execution. A vast amount of information was collected as to pollution conditions not only in New York Harbor but in various tributary areas. Elaborate investigations were also made of currents and volumes of fresh diluting water from the ocean, Long Island Sound and upland streams.

During this period of activity of the Metropolitan Sewerage Commission and agitation arising from the recommended Passaic Valley Project, New York instituted injunction proceedings in the United States Supreme Court seeking to prevent the execution of the Passaic Valley project. This litigation was active for nearly ten years. The injunction was denied without prejudice but in spite of interruptions due to the World War the whole question of elimination of pollution in this Region was greatly stimulated, as was the relation of the Federal Government to activities of this sort. In its opinion the United States Supreme Court made the significant suggestion that the sewage disposal problem presented by the growing populations living on the shores of New York Bay is one to be wisely solved by coöperative study and by conference and mutual concession on the part of the representatives of the states so vitally interested, rather than by proceedings in any court.

This period, from 1899 to 1919, may be characterized as one of substantial beginnings in the direction of coöperative or district undertakings in all three states. Litigation gave way to thorough-going investigations by state and municipal authorities and to increasing practical jurisdiction of state departments of health and state sewerage commissions. It is noteworthy, however, that largely by reason of litigation and the absence of adequate permissive legislation, over 20 years were required before the Passaic Valley project became an actuality.

Post War Advances in Legislation and Administration

Substantial progress has been made since the war in the development of better procedures for initiating, installing and administrating joint projects along inter-municipal, county, inter-county and interstate lines.

Westchester County.—Here in 1926 was established a County Sanitary Commission of three members serving without salary. The Commission investigated the different valleys with a view to setting up suitable district projects. It is dealing with seven projects in all, and has now made substantial progress with five. Some of these projects are practically complete and joint trunk sewers with joint treatment works supersede a number of individual local plants. The work is all done under the County Board of Supervisors, which must approve all plans before the work can be executed and also provide authorization of funds from the county, which reimburses itself eventually from assessments which it levies on the respective sanitary districts. Hearings must be held by the Commission and the County Supervisors, although objections need not be heeded. Thus substantial progress has been made with trunk sewers for seven sewerage districts, exclusive of the old Bronx Valley project, and for four joint treatment plants. At the end of 1930 appropriations have been made for projects approximating an aggregate cost of about $27,000,000 and preliminary studies and plans had been partially developed for other projects bringing the total appropriation ultimately sought for complete county-wide sanitation to $55,850,000. Two of these trunk sewer outlets discharge into Long Island Sound and two into the Hudson River after treatment provided by fine screening, chlorination and dispersion into deep water, a substantial distance from shore. Thus the Mamaroneck Valley project will discharge its effluent through a 54-inch pipe extending 2.42 miles into Long Island Sound, with the outlet 51 feet below sea level.

New York City.—Prior to the war the Board of Estimate and Apportionment created a Sewer Plan Commission to coöperate with the Metropolitan Sewerage Commission, and the office of the Chief Engineer continued its studies of local pollution and means of remedy until 1924, when the Board of Estimate established a Committee on Main Drainage. There are now two fine screening plants in Manhattan, one in Brooklyn, six in the Borough of Queens and two in the Borough of Richmond. Of this total of eleven plants, eight are of modern type while three are of older types. Several of the plants have been arranged with a view to having them serve ultimately as preliminary treatment for activated-sludge plants. The first activated-sludge plant to be authorized was that on Wards Island, which belongs to the city of New York but has been leased to the state for a hospital. Legislation permitted the city to recover from the state the use of 54 acres of this site on Wards Island in 1927 and the Board of Estimate and Apportionment established a special committee to initiate the program for design and construction. In 1928 and 1929 this undertaking was under the jurisdiction of the president of the Borough of Manhattan in conformity with charter provisions.

Department of Sanitation.—In November, 1929, a new central de-

partment of New York City was set up to take over, among other things, the installation of intercepting sewers, connecting tunnels and treatment works formerly in the hands of respective borough presidents. It is under this agency that two contracts were awarded in June, 1931, for the Wards Island activated-sludge plant, which has been completely designed as regards the treatment works, but for financial reasons appropriations have not yet been made for the remaining contracts. The cost of the Wards Island works will be met from the Street Improvement Fund, which is a revolving fund that will be reimbursed as contracts are completed from assessment against the entire city.

About a year ago the Sanitation Department of New York City issued a preliminary report on three separate plans for providing treatment of the sewage of the entire city of Greater New York to different degrees of completeness. In each plan are 33 individual projects, some of which would provide activated-sludge treatment, others sedimentation, depending upon the condition of adjacent waters, availability of sites, etc. These plans, depending upon the extent to which activated sludge or complete treatment would be afforded, are estimated to range from $243,560,000 to $377,935,000 and are assumed to take care of the needs of the city until 1960. Obviously it would require many years for completion of such installations even if there were no interruptions due to financing. Recently details have been developed for two projects; one in the Coney Island area and the other in the Newtown Creek area. It is sufficient here to refer to the plan as illustrative of the modern trend of concentrating the jurisdiction in the hands of one agency to provide for the collection and treatment of sewage for the present seven million people residing in New York City and for its future growth.

Hackensack Valley Sewerage Commission.—In New Jersey there have been several joint projects undertaken since the war but the chief advance in handling joint enterprises is represented by the recent report of the Hackensack Valley Sewerage Commission. It deals with an area of about 209 square miles in the valley parallel with the Hudson River, extending from Newark Bay into the state of New York. There are now 57 municipalities wholly or partly within the district and the present population is about 500,000 persons. The upper 115 square miles serves as the catchment area for the water supply furnished by the Hackensack Water Company. The tidal portion below New Milford, at times when there is little or no flow of upland water, shows material pollution, particularly in the creeks tributary to the main river. The sewage from Bayonne and Jersey City is also carried upstream by the tide.

The Commission recommends establishing a system of trunk sewers and conveying the sewage to two main treatment plants, which in the cost estimates were assumed to be of the activated-sludge type. On this area

there are now 40 municipal treatment plants, very few of which are adequate in size or type and there are also various industrial plants, about a dozen of which subject their waste to some treatment prior to discharge into the watercourses. A bill was introduced into the New Jersey Legislature to give effect to recommendations of the Commission which provide for the counties of Bergen and Hudson to issue temporary construction bonds to cover construction work, after the completion of which the temporary construction bonds would be retired by serial bonds and the two counties would be reimbursed by the various municipalities for the service rendered in accordance with a uniform rate per million gallons of sewage delivered into the trunk sewers. The recommended legislation provides that a petition against participation by any municipality, when signed by owners representing 60 per cent of the assessed valuation of real property, would bar such municipality from entering into a contract for service with the district. That is, if a municipality wished to assume full responsibility of conducting its own treatment works it could do so on the basis stated for declining to enter the District project, but it would be held responsible for delivering a suitable effluent from its individual plant. The proposed legislation leaves it optional with a municipality as to whether the cost of service by the district project would be met from tax levy or by a sewer-service charge or rental, or a combination of different methods as may be decided by the municipal authorities. The latter would be obligated, however, by contract with the district to provide in their annual appropriation bills the necessary funds to finance the cost of service by the district commission to the respective municipalities.

The Act to create a permanent commission for the Hackensack Valley Sewerage District and to provide for its program of financing and establishing contractual relations with the several municipalities has been held in committee because of difficulties in financing at this particular period. The preliminary commission making its report last winter has been continued for the purpose of making further investigations in the preparation of proposed contracts with municipalities for carrying out the program already outlined. The bringing of suits by the state against municipalities within the sewerage district relative to improvements to existing sewerage and sewage disposal facilities has been deferred until after May 1, 1933.

Proposed Interstate Sanitation Commission.—The report in February, 1932, of the Tri-State (New York, New Jersey and Connecticut) Treaty Commission defines the proposed treaty area as covering Long Island Sound on its northerly shore as far east as Morgan Point on the easterly side of New Haven Harbor and as far as Port Jefferson Harbor on the Long Island shore; on the south side of Long Island as far as Fire Island Inlet; the Hudson River and New York Bay below the New York-New Jersey state boundary together with estuarial and tidal waters related

thereto; and down the Jersey coast including estuaries and tidal waters to the southerly side of Manasquan Inlet. The report recommends that these waters shall be divided into two general classes.

Class A relates to water areas expected to be used primarily for recreation purposes, shellfish culture or the development of fish life. Before sewage is discharged into such waters there shall be removed all floating solids and at least 60 per cent of the suspended solids. The bacteria shall be reduced so that by the presumptive test the organisms of the *B. coli* group shall not exceed one per cubic centimeter in more than 50 per cent of the samples of effluent tested (with the qualification that for waters used primarily for bathing this bacterial requirement shall not apply except during the bathing season). The oxygen demand shall be reduced so as to maintain an average dissolved oxygen content in the vicinity of the point of effluent discharge at a depth about 5 feet below the surface at not less than 50 per cent saturation during any week of the year.

Class B relates to designated water areas not expected to be used primarily for recreational purposes, shellfish culture or the development of fish life. Before sewage is discharged into this class of waters it shall first be treated so as to remove all floating solids and at least 10 per cent of the suspended solids, and the oxygen demand shall be reduced so as to maintain not less than 30 per cent saturation during any week in the year in the vicinity of the point of discharge.

The recent report provides an interstate authority with the right to modify, after investigation, the above requirements as to removal of suspended solids and oxygen demand in parts of any municipality, provided the sewage from adjoining areas shall be treated so that the sewage discharged from the particular municipality as a whole meets the required standards.

Each signatory state is to pledge coöperation in the control of future pollution and is to agree to provide for the abatement of existing pollution. Each state is also to agree that sewage discharged within its jurisdiction into a tributary to the tidal waters of the Treaty Area shall be treated if necessary so that above its confluence with said tidal water the tributary shall be in a sanitary condition at least equal to the requirements laid down for the tidal waters into which it flows.

The Tri-State Pact, as recommended in the report, provides that a permanent Interstate Sanitation Commission shall be established whose duty shall be to conduct hearings and make investigations so as to prescribe a reasonable date on or before which each municipality shall treat its sewage in accordance with the above described standards specified in the Compact. The Interstate Commission is authorized to investigate and determine if the requirements of the Compact and its orders are compiled with and if satisfactory progress is not made then to bring

action in its own name, in the proper court, to compel enforcement of the provisions of the Compact and orders of the Interstate Commission.

The Compact provides that nothing in it shall be construed to repeal or prevent the enactment of legislation by any signatory state for imposing additional conditions and restrictions for preventing the pollution of the waters within its jurisdiction. The Compact also sets forth that the Interstate Commission shall coöperate with the respective state authorities having jurisdiction over stream pollution, with a view to coördinating activities and securing the most satisfactory results at reasonable cost. To this end the Interstate Commission is to prepare a general plan for submission to the Governor and Legislature and state agencies in charge of sewage problems in the respective states. Its powers are to supplement and in no case to limit the powers set up by the State Legislature and/or the Congress.

The Tri-State Treaty Commission makes no provision in regard to financing and its Committee on Research and Engineering recommends against giving the Interstate Commission power to issue bonds for construction pruposes, to prepare plans for sewage treatment projects and the right to approve or disapprove plans for new projects for alterations or extensions of existing plants, leaving these in the hands of local and state authorities.

The report of the Tri-State Treaty Commission with legislation to give effect to the Tri-State Compact as recommended was adopted unanimously by the Legislature of New York and signed by the Governor. Similar legislation is still pending before the New Jersey Legislature. In Connecticut the Legislature does not meet until January, 1933.

Summary

1. District or joint sewage disposal projects have grown progressively in the New York Region during the past 30 years and progress in that direction has never been so rapid as during the past few years.

2. District bonds have not been issued and in every instance funds have come from county, inter-county, municipal or inter-municipal sources.

3. The Tri-State Compact, setting forth an interstate commission on formal, legal lines to be ratified by the states in interest and by Congress, is believed to be the first comprehensive step of this kind.

4. Operation and maintenance expenses may be paid for by rentals according to recent New York legislation. In New Jersey it is feasible under the Home Rule Acts of 1917 to charge rentals to cover operation, maintenance and at least part of capital carrying charges. Sewer rentals have been frequently discussed and seem likely to be a coming factor in municipal finance of the Region.

5 The dilution method of sewage disposal is still the prevailing one and great improvements have been made in the use of submerged multiple outlets far removed from shore.

6. Fine screens are still held in favor for some conditions related chiefly to long, deep outfalls for the discharge of highly chlorinated effluent and also for some places where fine screens are assumed to be followed later by activated-sludge plants.

7. Sedimentation in newer installations is accomplished chiefly by single-story tanks, with the sludge removed by mechanical means for digestion in separate sludge-digestion tanks, provided with covers and arranged for use of the collected gas for heating the sludge.

8. Contact beds and sprinkling filters are rarely if ever proposed for new projects in this Region.

9. Sand beds find their place chiefly for small plants on streams tributary to domestic water supplies and where state authorities have required so-called complete treatment together with chlorination to be followed by sand beds.

10. Sludge from the sedimentation tanks at the Passaic Valley plant and New Haven is boated to sea and the same step has been provided for part of the sludge from the Wards Island plant.

11. Vacuum filters for dewatering sludge are receiving active consideration for several projects in this Region, although conversion of the filter cake into fertilizer is meeting unfavorable commercial conditions.

12. Incineration of dewatered sludge is meeting more and more favor.

13. Sewage disposal betterments are still being retarded in this Region by the requirement of the Public Health Laws that State Authorities have to prove *actual* injury rather than *potential* menace to the public health and property. This situation spells delay either through procrastination or the formalities of litigation in courts of original jurisdiction and appeals from the decisions thereof.

A Quarter Century of Progress in Sewage Treatment*

BY LANGDON PEARSE

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My personal recollections of developments in The Sanitary District of Chicago run back nearly thirty years. I first saw the work of the District in 1903, when the extension to the power house at Lockport was under construction. Curiously enough, I was then in Mr. Whipple's office and worked on the Missouri side of the Missouri and Illinois case, so I had an opportunity to study in a very early stage the litigation and the problems that were ahead.

I came to the District in 1909 and undertook the development of its sanitary engineering work. In those days the outlook for sewage disposal was largely one of dilution, although the then Chief Engineer, Mr. George M. Wisner, realized that supplementary measures would have to be provided. The effects of the growth of Chicago and its industries were beginning to show in the load upon the Main Channel. Investigations began first by operation of testing stations. For several years various devices were operated at the Thirty-Ninth Street Pumping Station on domestic sewage, which provided information of value on the efficiency of apparatus such as screens, settling basins, Imhoff tanks, trickling filters and the like.

One of the most interesting developments was the nitrate method for the determination of biological oxygen demand and the stimulus thus given to the use of the B. O. D. method as a test. At the time, it seemed highly desirable in our contact with laymen to have one general test which would cover a much wider ground than the old-fashioned strictly chemical procedures.

Another testing station was erected at the Stockyards. In connection therewith the industrial wastes from Packingtown were investigated, and found to be a large proportion of the industrial load that came to the Main Channel. A later checkup in 1917 showed that the wastes from Packingtown were equivalent to about a million people. The Stockyards testing station covered not only the use of settling tanks and sludge digestion, but screens and activated sludge, and included one of the earlier activated-sludge testing plants in this section. As I recall, Milwaukee, and perhaps the State Water Survey at Urbana were ahead in testing the application of activated sludge.

After the World War, the tannery problem was taken up, including the

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inspection of some forty different tanneries and wool pulleries. A testing station was operated at the Griess-Pfleger plant. This showed the difficulty of handling tannery waste as such, and the need of separating heavy alkaline-lime sludges. This work led to the conclusion that for our purposes—and I think it has also been true with other similar situations elsewhere—the best procedure was to remove the heavy settling solids, such as lime sludge, at the tannery and to allow the settled wastes to mix with sewage for treatment.

Next, the Corn Products Testing Station was operated at the plant of the Corn Products Refining Company. This was an industry grinding daily seventy-five thousand bushels of corn, with a waste to the Main Channel equivalent to the sewage of about four hundred and fifty thousand people, quite an increment on top of the million population equivalent from Packingtown. The first effort was to try the effect of treatment of corn products wastes by settling, activated sludge, trickling filters and the like. By the nitrogen determinations obtained on the outlet sewer, it became evident that there were certain losses in the plant which did not agree with the plant analyses. As a result, the company developed an automatic sampling device to put on the outlet of various houses or processes to obtain a composite sample over 24 hours. That alone saved $70,000 a year. What had happened was that collectors in the various houses developed the quaint idea that what the plant superintendent wanted was a sample of the best looking effluent. Consequently the samples were collected only when the losses were lowest. Samples collected at the outlet of the plant revealed the discrepancy. The automatic devices have been somewhat modified and used in the larger Sanitary District plants, proving very satisfactory for sampling.

However, the solution of the Corn Products problem came along different lines. The experts of the company discovered that a process was worth adopting which had formerly been tried and shelved, because in the old days the quality of the starch was supposed to be affected. A scheme was worked out for bottling up the wastes and, by subsequent filtration, removing the solids, which were then dried and added to the feed. By remodeling the plant flow sheet along these lines, a substantial recovery has been made, which is said to produce a profit. Formerly, 3 to 5 per cent of the grind were common losses in the corn products industry. I can remember the expression of astonishment on our Chief's face when I told him the factory was losing in effect 3 per cent of the grind, equivalent to some 2250 bushels of corn down the stream per day. Although absorbed as a manufacturing cost in the industry, the loss meant difficulty in the sewage problem. The bottling-up method was applied at Pekin and other plants and, I understand, has proved quite satisfactory. However, the Corn Products Refining Company is still working on the problem, seeking certain modifications

in the flow sheet or processes to improve the efficiency of bottling-up and to increase the removal of organic matter within the plant. The pollution has been reduced to a figure varying from 60,000 to 85,000 population-equivalent, varying with the grind and the flow sheet in the plant.

Another source of trouble has been paint and chemical wastes in the Calumet area. These wastes affected the trickling-filter and the activated-sludge units, reducing the yield to half the normal rate, and coloring the effluent. The wastes included waste acid and residues from the manufacture of anilin dyes and insecticides. Arsenic, mineral and organic acids, as well as dye wastes, are discharged. With the coöperation of the paint industry, the effect of discharge of objectionable material to the sewer has been reduced, particularly by arranging for uniform discharge by installation of storage tanks.

One interesting feature crops up in industrial plants with many departments. There seems to be a tendency to charge the cost of treatment of the waste to the particular department that makes the product from which the waste comes. Consequently, the urge to clean up the waste appears to be lessened, as the department has to show a higher manufacturing cost for its product and hesitates to make an improvement. It would seem as though the costs ought to be absorbed by the plant as a whole, as part of its general manufacturing cost or overhead, because of the location of the plant, and not charged directly against the particular department.

The work with the Corn Products Refining Company was particularly successful, on account of the friendly coöperative attitude of the industry. With the Packers, a different history is revealed. Relations were apparently friendly up to 1919, until the end of the War, when profits fell off. At that time the Packers had offered to enter into an agreement with the Sanitary District to treat their sewage and pay 60 per cent of the construction and operation costs. With delay came further losses of income, with the result that of late years the Packers have refused to do anything at all. At present the Sanitary District has suits pending in the Federal and State Courts. In the Federal proceeding, there is some expectation that a hearing will shortly be reached before a Master, of cases against certain of the Packers which are not citizens of Illinois. The issues involved are:

First—The right to enter the plant and obtain information (inasmuch as the Packers refuse to allow entry to employees of the Sanitary District), and

Second—Whether or not the Packers should be enjoined from discharging their waste and sewage into the sewers, canals or streams within the Sanitary District.

On the basis of data built up from industrial and domestic surveys from 1919 on, the engineering force of the Sanitary District proceeded to shape up the program of sewage treatment. The necessity of supplemental treatment to aid dilution was realized. The District was divided into a

number of project areas, of which the four main projects are: West Side, North Side, Southwest Side, Calumet. The Des Plaines River project appeared in the original scheme, but has since been merged with the West Side. In connection with the surveys the District has been making with the coöperation of the State Sanitary Water Board and the Cook County Forest Preserve, we are studying temporary measures for improvement of the condition of the Des Plaines River, the North Branch of the Chicago River and certain sparsely settled localities, that will aid in cleaning up the stream prior to the completion of the ultimate project.

The sewage treatment program of the Sanitary District has been discussed at length in various phases, both in litigation in Washington and in the press, so I will not go into details, except to say that at present the District has in operation plants treating the sewage of about two million by one form of treatment or another. This does not mean, of course, one hundred per cent purification, but simply the population which is tributary. Some of the plants are principally sedimentation. The Calumet Works contains thirty Imhoff tanks with two units of activated sludge and a trickling filter. The West Side plant consists of two batteries of Imhoff tanks, and a third battery is under construction.

The North Side Works is of the activated-sludge type and handles the sewage of more than a million people, with a flow of over two hundred million gallons per day. It has been in operation with a full load for two years. In connection with that plant, the trend of the population movement is of interest. The tributary population was originally estimated at about 810,000 for 1930. Actually, the 1930 census shows very close to a million people. Evidently in that section there has been a decided movement of population from the inner area around the loop, to the northwest, which has materially increased the normal growth on that area. Increases to a similar extent do not appear in other parts of the District, although there is a tendency on the West Side for the population to move out of the congested areas into the suburban areas.

The North Side Works have been giving good results. The economies secured in the use of air are particularly pleasing, running less than one-half of a cubic foot of air per gallon of sewage—very much lower than originally estimated. Various tests have been conducted on methods of operation, such as the use of pulsating air and running one battery with sewage containing practically all its solids, instead of sewage that has been given preliminary treatment. Settling basins have been tested, as well as the efficiency of various widths of aeration tanks with spiral flow. Results of these tests will lead to improved design of future plants.

The sludge from the North Side Works is pumped to the West Side plant and is there digested, insofar as practicable.

Perhaps one of the most interesting problems that I can dwell on is the

question of handling the solids in sewage treatment. What brought this home to us was the fact that in designing the West Side Works, with the deep Imhoff tanks installed, a moisture content of digested sludge was expected of 86 to 87 per cent moisture. In handling the mixture of fresh and activated sludge by digestion, the activated sludge is pumped from the North Side together with the raw solids from the preliminary basins, and mixed with the settled solids from the West Side. The digestion of mixed solids, however, has resulted in need for greater digestion capacity than originally contemplated. The moisture content will seemingly not drop below 94 or 95 per cent. Heating apparently makes little difference in the moisture content. To study the problem for future plants, two separate digestion tanks were installed, of steel and of considerable size, and operated as separate-digestion tanks with heat. Short digestion periods, with heat, apparently will not reduce the moisture content below 94 per cent. The heated sludge is viscous and sticky, different from that of an Imhoff tank.

For some years we have had in mind the possibility of dewatering sludges by the use of a centrifuge or mechanical filter. The value of a centrifuge has been debatable based on the results of the excellent work done in Milwaukee and Baltimore some years back on centrifuging activated and digested sludge. However, the possibilities appeared to be worth following up. Our Chief Engineer secured authority to enter into a contract with the Evers-Sauvage Engineering Company, of Chicago, to develop a machine to handle one hundred gallons of sludge per minute. This apparatus is designed to operate continuously at very much higher speeds than used heretofore, with certain devices for concentration and separation of the liquids. The speeds probably will be 4000 to 5000 revolutions per minute, with a bowl five feet deep and not over 16 inches diameter. The first try-out is planned for concentration of sludge rather than making a cake. The machine is now practically developed and ready for construction, which has been deferred for the present. On a small scale, preliminary tests showed a reduction of the suspended matter in the effluent to 500 parts per million or less. The question is one of capacity, and whether or not a cake can be made with sufficient output, together with suspended matter in the effluent low enough to avoid trouble such as happened in Milwaukee in the old days with return of finely divided sludge.

On the other hand, the application of vacuum filters to sludge has been taken up, with the purpose of dewatering and making a cake which can be incinerated. The solids obtained from sewage by settling may show a fuel value about half that of Illinois coal. Such sludge can be burned with or without additional fuel. How much combustion it can support with its own fuel content depends upon the amount of moisture present.

Tests have been made principally with mixed sludge, activated and fresh, with the intention of entirely eliminating digestion and sand drying

beds. This appears to be the most economical line to follow. From the results to date, we have had considerable encouragement at the West Side. Ferric chloride has been used as a conditioner, in amount about 5 per cent of the dry weight of sludge. The dosed sludge should be applied to the filter as quickly as possible. In general, with the sludge tested, cake has been produced at a rate around three pounds of dry solids per square foot of filter area per hour. At times the rate has risen to six or eight pounds per hour, but not continuously enough to be counted upon as a steady output. The moisture content is around 80 per cent for fresh mixed sludge.

Experiments have been made on the incineration of the filter cake and other sludges. Different types of grates have been tried, in particular, the Harrington grate, made by the Whiting Corporation at Harvey, Illinois. This is a movable type of grate which prevents sealing of the grate bars by the formation of a cinder or slag.

The sludge apparently burns fairly readily, with a minimum odor. With the moisture content around 70 per cent or higher, it is necessary to add some coal or other fuel. To determine the results on a large working scale, before reaching a decision on the dewatering and incineration process, our Chief Engineer obtained authority to build a plant handling 20 tons of dry solids per day at the West Side. This plant includes an Oliver vacuum filter, a rotary heat drier for reducing the moisture content preparatory to incineration, and a combustion furnace, including the Harrington grate The hot gases from the burning of the sludge, to which is expected to be added 350 pounds of coal per ton of dry solids, pass back through the rotary heat drier. An inert cindercake residue is left, resembling a clinker with probably less than one per cent of organic matter, something entirely inodorous, and suitable to dump and forget. It is possible it may have a value as cinder, but it certainly will make good filling. Without the coal, it has a reddish color; with the coal, it is of a black reddish tint. The test plant should be in operation by the end of July, 1932.

In working up the cost estimates, factors were studied such as the variation in the suspended solids coming to the plant. From the operating records at Calumet, for instance, the peak day showed up as five times the average production of solids, as shown on the yearly average day. To install machinery for such a daily rate might not be desirable. However, by utilizing the storage in the activated-sludge part of the system, machinery and equipment would have to be installed for two and one-half times the yearly average. Variations in daily input of solids has not bothered the designer of Imhoff tanks. It may become more important in designing separate digestion tanks, with relatively short periods of digestion.

Preliminary cost figures for filtration and incineration are interesting, but not conclusive as yet. The first cost is very much less, in comparison

with the settling and sludge handling part of the usual sewage plant, because of the omission of all digestion capacity, air-drying beds and other collateral equipment. The operating costs apparently may be somewhat less, as well as the total annual costs, including operation, maintenance and the like. The indications point to enough saving to make the investigation well worth while.

The preparation of the solids before combustion apparently is worth while, by a combination of methods to lower the moisture content. If it is approximately seventy per cent, the B. t. u. of such solids as we have may supply enough fuel value to evaporate the moisture and burn up the sludge. In going from a vacuum filter to a rotary dryer or similar device, it seems practical to carry the moisture down to 20 per cent, more or less, before incinerating the sludge.

There is still the problem of odor. This does not appear insuperable because the temperature of combustion is planned to be above 1500° Fahrenheit. If sludge is burned at low temperatures, however, around 300 to 500°, tests in the laboratory indicate that objectionable odors will be produced. Evidence from the practice of garbage incineration point to the desirability of temperatures over 1000° as distinctly advisable.

In the general development, the Sanitary District has studied the use of sludge as a fertilizer, but has taken a somewhat different path from Milwaukee. With equipment for dewatering and incinerating activated sludge when times are good and the market will absorb the material, the District could make and sell dried, activated sludge. But it is doubtful if there would be a market for both Milwaukee and Chicago, if the District endeavored to market a production daily of 500 or 600 tons of material on top of 100 tons from Milwaukee.

The work of the District has run along, as this brief sketch shows, through the various trends of sewage treatment, over the past twenty-five years. From the original work of Dr. Lederer on nitrates, came the valuation of sewage treatment, on the basis of equivalent population and the testing of efficiency with the aid of biochemical oxygen demand tests. While such a test originated in England years ago, the test was not used then as it is now used in this country.

The proposed process of dewatering and incinerating sludge, a problem which for the District, at least, is on a big scale, may have quite a bearing on sewage treatment practice if present expectations are fulfilled.

Another phase of engineering work has been the contacts with litigation, such as the cases of Missouri *vs.* Illinois, United States *vs.* Sanitary District, and Wisconsin *et al. vs.* Illinois *et al.* In addition are the activated-sludge patent case and the Packingtown case. The first three cases cited made history, because through the chain has come about the establishment of a legal precedent whereby it became easier for New York legally to obtain

water from the Delaware River watershed and for Metropolitan Boston to take water from the Connecticut River watershed. Therefore, the Sanitary District litigation has a bearing in the shaping of sanitary precedent.

The immediate future prospects of the Sanitary District are somewhat disturbing. It is up against the problem of finance, just as many others are throughout the country. It has been unable to sell any bonds since early last Fall. Taxes are coming in slowly, with a delay of nearly two years due to revaluation. The contract work is all shut down, except for the twenty-ton test plant. Many of the engineering staff have been discharged. The operating staff has been trimmed down. Economies are being made. It is hoped that in the near future conditions will improve so that the program may actively be resumed.

If the results of the studies in design and operation of the new sludge handling process work out satisfactorily, there will be a considerable economy in the total cost of the District program. The lower construction costs now obtainable will also be helpful.

In conclusion, I want to express my appreciation, during the years that I have been with the District, for the support the engineering staff has received from our various Chief Engineers. Developments such as I have mentioned represent the work of an organization. Mr. George M. Wisner has been active for many years, first as Chief Engineer and later as Consulting Engineer. His initiative and foresight laid the foundations of the sanitary developments. Mr. Edward J. Kelly has now been Chief Engineer for some ten or more years. The support he has given has aided in carrying out the sanitary developments. Mr. Philip Harrington, the Principal Assistant Chief Engineer, has encouraged the research and taken a lively interest in the problems of economy of operation and improvement of design. The mechanical engineering work described has been conducted by the Mechanical Engineer, Mr. William Dundas, whose knowledge of handling heat and mechanical developments have materially aided. Dr. F. W. Mohlman, our Chemist, whom you all know, has been working on the chemical and biological problems. And, finally, the results represent the work of the engineering staff, who have aided in carrying out all the details.

There is little more that can be said in the time available. A large program looms ahead for execution, if the Sanitary District is to fulfil the terms of the decree under which it is working, from the Supreme Court of the United States. Much construction work above and below ground has been completed, representing material achievement. Individually and collectively, the Sanitary District and its employees have contributed toward the advancement of the treatment of sewage and to sanitation generally, as well as to the establishment of some precedents in legal phases which are helpful to others as well as to ourselves.

Overloaded Trickling Filter Plant Relieved by Sedimentation and Chlorination of Excess Flow*

BY A. L. THOLIN

Sanitary Engineer, Downers Grove, Illinois

There are conditions under which it is not wise to achieve the ultimate degree of purification of sewage. There are times and conditions when a reasonable degree of purification through treatment works so built as to allow for progressive development is the correct present answer to a community's problem. It is believed that such a time and condition now exist in the Downers Grove Sanitary District and probably in a great many other communities.

The Downers Grove Sanitary District, including most of the villages of Downers Grove and Westmont, is located along the C. B. & Q. Railroad, twenty miles southwest of Chicago. It has a present population of approximately 11,500 people, about 95 per cent of which is now connected to its system of sanitary sewers. It was one of the first districts to be organized under the Legislative Act of the State of Illinois commonly known as the Act of 1917. When organized in 1920 it had a population of about 3500 people.

In 1923 the village of Westmont was incorporated, and for five or six years it grew like a mushroom astride the district's eastern boundary. The growth of Westmont, coupled with the rapid growth of Downers Grove, increased the population of the district to about its present population by the year 1929. Since then there has been no perceptible growth.

This paper is written to present a view of the project which has just been completed at the Downers Grove Sanitary District. The basis of the project and the plans and specifications were prepared by the writer, in conjunction with W. T. McClenahan of Chicago. The construction work was supervised and inspected by the Wells Engineering Company of Geneva, Illinois. Thorgersen and Ericksen Co. of Chicago were the general contractors.

The writer will, first, present the problem as of the year 1930, then show the plan as adopted and constructed, and finally a view of the plant as it is today.

The Downers Grove Sanitary District is situated on the watershed of the DuPage River. All of the district drains into a small dry-run creek known as St. Joseph's Creek, which originates within the district and flows westward, parallel, approximately, to the C. B. & Q. Railroad, to a junction with the east branch of the DuPage River in the middle of the small unincorporated community known as Lisle.

* *Presented before the Joint Meeting of the Illinois Association of Sanitary Districts and the Central States Sewage Works Association, Rockford, Ill., May 14, 1932.*

Above its junction with St. Joseph's Creek, the east branch of the DuPage River receives some pollution from the villages of Lombard and Glen Ellyn, about six miles north of Lisle. Below its junction with St. Joseph's Creek, the east branch flows south and away from urban development. About six miles south of Lisle the east branch turns westward for a distance of about four miles to join the west branch of the DuPage River, which in turn has received the sewage, treated or otherwise, from four communities; namely, Wheaton, Winfield, West Chicago and Naperville. From the junction of the two branches, the DuPage River flows southwesterly to join the DesPlaines River, directly opposite its junction with the Kankakee River—these three rivers together forming the Illinois River. About seven miles south of the junction of the two branches of the DuPage River lies the small farming community of Plainfield.

The drainage of this river system and especially the location and direction of flow of St. Joseph's Creek entered into the problem very definitely because of the fact that St. Joseph's Creek parallels the most probable line of urban development, namely, along the C. B. & Q. Railroad.

To any one who is familiar with the map of Chicago and environs, it is not necessary to recall to mind the fact that the suburban towns stretch out along the lines of railroads—like fingers on the hand. As soon as the development of the Chicago area, which has been slow in the past three years, begins again, it is logical to assume that the density of population along St. Joseph's Creek between Downers Grove and Lisle will increase and Lisle will become the nucleus of another town.

Assuming this view-point to be correct, the logical location for a sewage treatment works for both Downers Grove and Lisle will at some future date be along the east branch of the DuPage River, two or three miles south of the railroad. No matter how complete or elaborate a sewage treatment works for the Downers Grove Sanitary District might be, the presence of a small creek, containing, in the summer months, nothing but the effluent from a sewage treatments works, would be objectionable in a highly developed residential community. It may be five or it may be twenty-five years before such a condition will develop, west of Downers Grove.

In order to determine the oxygen conditions of the DuPage River and St. Joseph's Creek and their capacity for natural purification, five series of tests were made at critical periods in the dry season of 1930. The oxygen demand and the oxygen content of these streams were found at nine or ten different locations. In general, these tests indicated that the East Branch of the DuPage River had almost entirely overcome the effects of pollution by the time it reached a point three or four miles south of Lisle.

In considering the Downers Grove Sanitary District, alone, it was found that it had a separate system of sanitary sewers with two main sewers, one twenty-four inches and one forty-two inches in diameter, leading into a

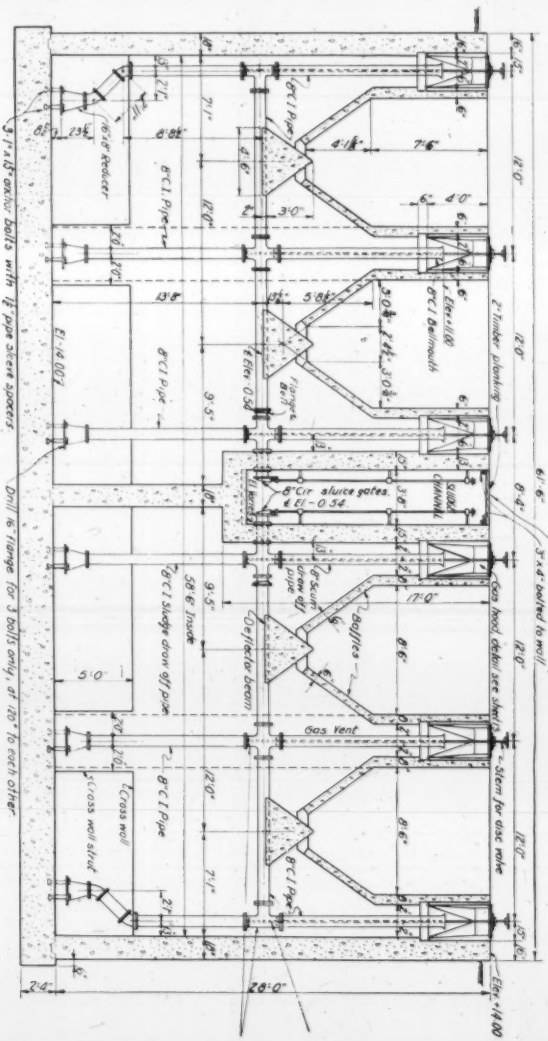
Bore holes in planking for insertion of valve key
3"x4" bolted to wall
Gas hood, detail see sheet
Stem for disc valve
Gas Vent
Baffles
Deflector beam
8"Cir sluice gates @ El - 0.54
SLUICE CHANNEL
2" Timber planking
8"CI Pipe
8"CI Bellmouth
8"CI sludge draw off pipe
Cross wall
Cross wall strut
Drill for flange for J bolts only, at 120° to each other
3"x4"x15" anchor bolts with 1½" pipe sleeve spacers
28'0"
Elev +14.00

FIG. 1.—Cross-Section of Imhoff Tanks at Downers Grove, Illinois.

small Imhoff tank and trickling-filter plant built by the Sanitary District in 1921 and 1922.

It was found that the existing plant was designed and placed at such a level as to handle only the sewage flow from the twenty-four inch sewer. The forty-two inch sewer enters the plant site with its invert about one foot lower than the invert of the twenty-four inch sewer. A stop-log dam had been built across the forty-two inch sewer high enough to divert its flow in dry weather into the existing plant, but this dam created a pond in the last half-mile of the forty-two inch sewer, with velocities low enough to produce settling, scum formation and a very stale sewage entering the plant. Odors from this plant were a real problem, due to the number of closely adjacent homes.

A chart of daily sewage flows for the year 1930, indicated an unusual fluctuation in quantities of sewage flow for a system of sewers which is called separate. Dry weather flows were less than one million gallons per day, and peak flows during the wet seasons, reached a maximum of fifteen million gallons per day. The extreme peaks can probably be accounted for by illegal roof drains or other storm-water connections, and the gradually diminishing, but large, flows which follow the peaks as leakage into sewer lines laid through marshy districts in which there is no other form of drainage.

With more than 75 per cent of the area of the district sewered and 75 miles of sewers at the present time, it can be expected that the peak flows may not increase and may actually diminish in the future as the district develops and storm water drains are added, thereby eliminating the swamps and lowering the general ground-water level.

Summarizing the problem then, as it existed in 1930, there was a community whose growth was hard to forecast, a sturdy little treatment works with a capacity, in population, of about half of the tributary population, discharging its effluent into a creek which could not be considered the ultimate means of disposal, and the stream, which will finally be the means of disposal, too far from the present district boundaries to allow the District to move its plant to the larger stream because of the excess financial burden.

Looking at the financial condition of the District, it was found that the maximum bonding power, under the law, amounted to less than $175,000—that $22,500 worth of bonds, issued for the construction of the existing plant, were still outstanding, to be retired in the year 1930, 1931 and 1932. As of the year 1930, then, the district was able to increase its indebtedness to the extent of about $150,000.

The problem was, therefore, to formulate a plan whereby satisfactory treatment could be given to all of the sewage of the Downers Grove Sanitary District for some years in the future and to limit the cost of such a plan to

an amount less than $150,000. The cost of the plan adopted was approximately $122,000 and included the following features:

A coarse bar screen with one-inch clear openings was built across the two incoming sewers. A separate screen was provided for each sewer with a partition wall separating the two screens and having an overflow weir set in an opening through the wall. The water level behind the small screen will, normally, be about nine inches higher than the water level behind the large screen. The sewage from the 24-inch sewer is thus diverted into the old plant in dry weather, but when the higher flows come in wet weather, the excess will overflow into the 42-inch sewer and continue to the new layout.

This arrangement eliminated the objectionable ponding which formerly

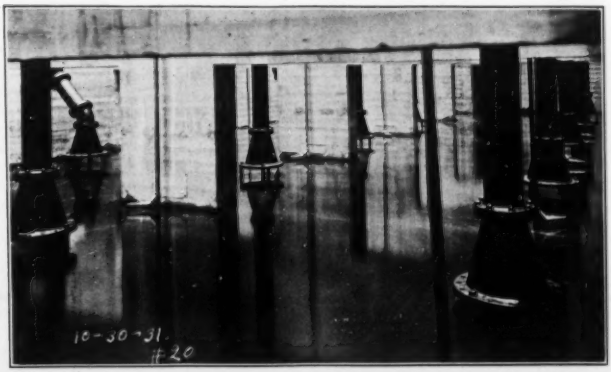

FIG. 2.—Bottom of Imhoff Tanks. Note Rotating Brass Nozzles for Under-Cutting Sludge.

existed in the 42-inch sewer. All sewage, then, in excess of the capacity of the old plant will continue along the 42-inch sewer to a diversion manhole. Out of this diversion manhole are three outlets, one leading through a venturi meter—with a maximum capacity of 7 m. g. d.; another outlet leading into an 18-inch meter by-pass line with an additional capacity of 8 m. g. d.; and the third outlet being by overflow of a stop-log dam into a 30-inch sewer leading directly to the creek. No sewage passes through this outlet unless the total flow into the plant site is in excess of 16 m. g. d.

The collecting sewers from both ends of the new Imhoff tanks lead into a collecting manhole, and from there a sewer leads directly to the creek. Four sludge beds, each 25 by 100 feet, were constructed along the bank of

the creek, with provision in the layout for six additional beds. No additional trickling filters were built. With a limited amount of money to spend, it was thought better to eliminate the visible solids from all of the sewage than to provide complete treatment for only a part of it, or, perhaps, all of it during a part of the year. However, by not providing any further secondary treatment it was assumed that the oxygen demand of the tank effluent would, in the dry season of the year, exceed the oxygen supply furnished in the trickling filter effluent and by reaeration and subsequent dilution in St. Joseph's Creek between the treatment works and Lisle.

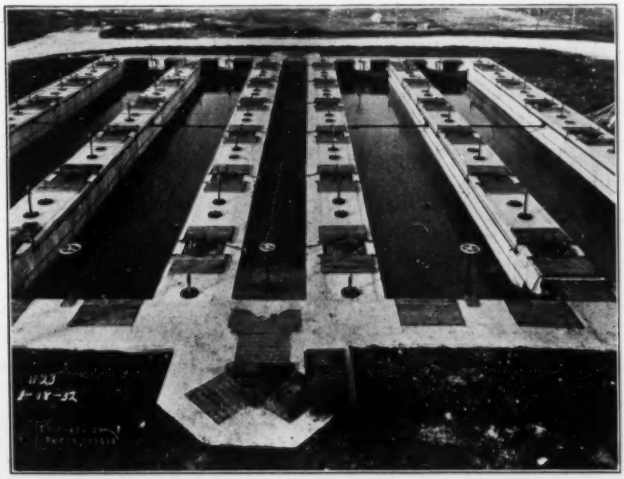

FIG. 3.—Imhoff Tanks, Downers Grove, Illinois, Showing Gas Hoods, Brass Water Pipes and Disk Valves.

Chlorination was installed to retard the oxygen demand of the tank effluent until it was far enough down stream to be satisfied by the natural processes of stream purification. Chlorination was also deemed desirable to eliminate odors about the plant. In dry seasons the ratio of filter effluent to chlorinated tank effluent will be about one to one.

Figure 1 shows a section through the new Imhoff tanks. They represent a departure from the standard design in that they have flat bottoms. The gas vents are partially sealed with concrete plugs and in the remaining openings are set gas-collecting hoods.

The plant is in very close proximity to homes and gas collection was not only desirable but necessary if the plant was to remain at its present location.

There is a sludge channel between the two tanks. There are six horizontal sludge-collecting lines leading into this channel from each tank. From each collecting line are three branches from inside the gas-collecting hoods and three branches from the sludge compartment. Working in the tees and crosses of these collecting lines is a specially designed double-disk valve with a stem extending upward through the center of the hood.

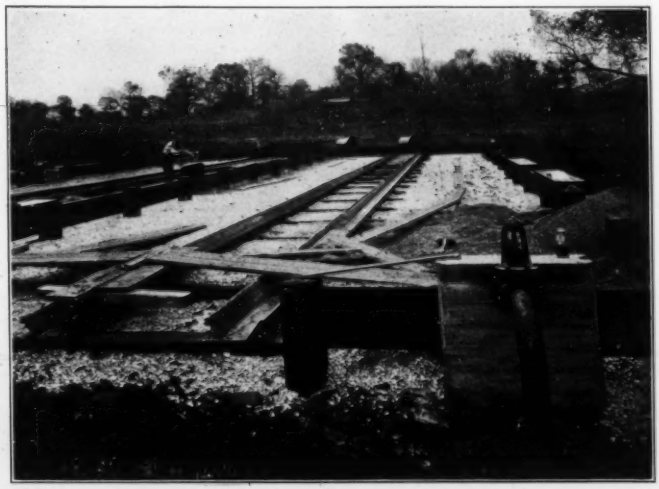

FIG. 4.—Sludge Beds, with Runway for Truck.

When the valve is raised so that both disks are above the collecting line, sludge is drawn from the bottom of the tank. When the valve is lowered so both disks are below the collecting line, scum is collected from under the hood. When the valve is at a neutral position, scum or sludge can be removed from some other point on that line.

The flat bottoms and the system of piping shown allow sludge or scum to be withdrawn from eighteen different points in each tank. The flat bottoms were also considered economical due to simplicity of construction.

Figure 2 shows the lower portion of the sludge compartment of one of the

tanks, with a few inches of water covering the floor. Note the spacing of the sludge draw-off pipes and also note the rotating brass nozzles for undercutting any sludge accumulation between the draw-off pipes. The upper end of the brass pipe, leading to the nozzles, extends above the top of the tank terminating in a hose connection for connecting to a nearby hydrant. Just below the hose connection is a tee for inserting a handle to rotate the entire assembly.

Figure 3 shows the completed tanks filled with sewage, the view being taken from the roof of the main building. Note the round tops of the gas

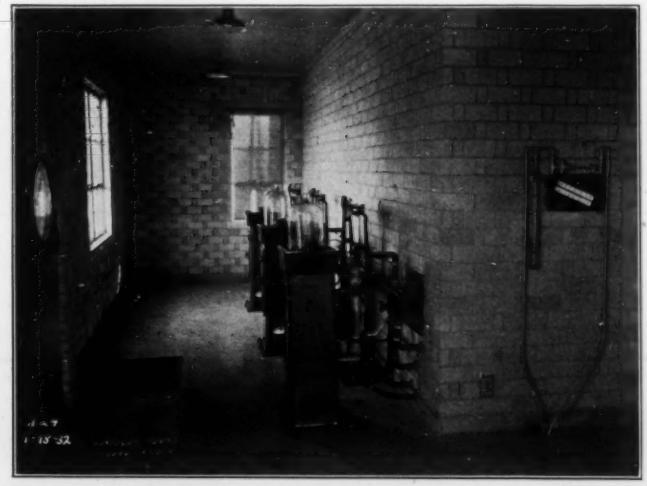

FIG. 5.—Battery of Chlorine-Control Units. Scales and Chlorine in Opposite Room Behind Wall.

hoods set at regular intervals in the gas vent area, and the brass pipe, just referred to, extending above the top of the tank between each pair of hoods. Also note the handle and valve stems of the double disk valves extending out of the center of each hood. To prevent the escape of gas around these valve stems a 1½-inch pipe was screwed into the under side of the top of the hood and extended a little more than a foot below the water level in the tank.

Figure 4 shows the construction of the sludge-drying beds. The 4-inch pipe in the foreground is the sludge-discharge pipe. A truck runway of

deep arch steel sheet piling, spiked to railroad cross ties, was built in the center of each bed.

Figure 5 shows the battery of chlorinators in the main building. One platform scale was provided for each chlorinator. The scale beams can be seen in the picture between each pair of chlorinators. The scale platforms, however, are on the opposite side of the wall, in the chlorine storage room and most of the piping is fastened to the store room side of the wall. The piping and solution hose lines are so arranged that any chlorinator may receive chlorine from any scale platform and deliver chlorine solution to any one of three places in the plant; namely, the 24-inch sewer leading into the old plant, the dividing manhole through which the raw sewage flows as

FIG. 6.—Layout of Downers Grove Treatment Works.

it enters the new tanks, and the collecting manhole through which the new tank effluent flows on its way to the creek.

The plant has been in operation since the first of this year (1932) but has not yet passed through the critical period of a dry season. From present indications, it is believed that satisfactory conditions can be maintained in St. Joseph's Creek at all times and for some years in the future, without any further additions to the treatment works.

In wet seasons all of the sewage up to 16 m. g. d. will receive at least sedimentation and fine screening, for across the outlet of the new Imhoff tanks is placed a brass plate screen with one-eighth inch slotted openings.

No difficulty has been encountered in keeping these screens clean under all conditions of flow. They are cleaned two or three times a day. In periods of extremely small flows the trickling filter effluent will approximately equal the chlorinated tank effluent and if the filter effluent contains an oxygen content of seven parts per million the mixture of the two will leave the plant with an oxygen content of at least three and one-half parts per million, assuming that the tank effluent has no oxygen of its own.

The chlorine should prevent the oxygen demand from depleting this supply until the effluent has reached the east branch of the DuPage River at Lisle where it receives additional dilution. It should also prevent any excess growth of sewage organisms in the stream.

Figure 6 is a view of the completed plant. The incinerator in the background, to the left, is for the purpose of burning waste gas and also the screenings from the coarse screens alongside it.

Wild-Flower Planting about Sewage Treatment Works*

BY EARLE B. PHELPS

Professor of Sanitary Science, Columbia University

In a recent paper in THIS JOURNAL relating to the landscaping of sewage treatment works and grounds, the point is developed that engineering utility is the test of good decoration. The author does not, of course, follow this thought through to its limit, for that would give us bare unsmoothed concrete walls, and turn back a most desirable present-day trend toward buildings that are architecturally pleasing as well as useful. He merely protests, and very properly, against trying to convert sewage works grounds into botanical gardens or recreation parks. This, it is said, makes more conspicuous a thing which should be made less so.

The present title happens to combine a vocation and an avocation of the writer, who would not care to be pressed to state which is which. It does seem, however, that the use of the natural wild species of the region, many of the so-called weeds in fact, offer a solution of the question of suitable adornment which meets all the specifications.

In the first place while exotic planting, formal rows of geraniums for example, makes the grounds more conspicuous, natural planting can make them far less conspicuous than unadorned walls and bankings. In fact, we apply nature's own principle of protective coloration, so successfully employed by wild life when the object is to become indistinguishable. Furthermore, the material is available at low first cost; if selected from near-by it will surely thrive and multiply; and finally, of great importance, it demands no fertilizing, sprinkling, weeding, pruning, clipping, or mowing—in brief, it is self-maintaining.

By way of example, consider an embankment covered in the conventional manner with grass. Custom dictates that to be kept neat the grass must be mowed, an expensive and difficult task. In dry weather it must be sprinkled and dandelion, plaintain and annual grass must be fought at all times. Frequently it winter-kills in patches and must be resown. Let us cover this banking now with the common, wild ground ivy or gill-on-the-ground (*Nepeta Glechoma*), a wild thing whose preferred habitat is an ash dump. It will rapidly cover any area with dense, insect-proof foliage through which few weeds can penetrate, with a fine mass of blue flowers in the spring, good autumn coloring and seeds attractive to the winter birds—and all this without a cent for upkeep. Put in some patches of common daisies (*Chrysanthemum Leucanthemum*) for June

* *Discussion before the June, 1932, Meeting of the New York State Sewage Works Association at Buffalo.*

LIST OF WILD PLANTS, SUITABLE FOR USE ABOUT SEWAGE TREATMENT WORKS AND GROUNDS. PREPARED BY MRS. JOHN M. SKINNER

Name	Type			Use			Habitat			Flowering		
	Trees	Shrubs	Herbaceous	Ground Cover	Screen	Walls	Shady Woods	Sunny Fields	Moist Ground	Color	Season	Remarks
Arrowhead (*Sagittaria variabilis*)			x						x	White	June and July	
Arrowhead (*Sagittaria latifolia*)			x						x	White	July to Sept.	
Arum (*Calla palustris*)			x						x	Greenish white	May and June	
Bee Balm (*Monarda didyma*)												
Oswego Tea			x						x	Scarlet	July to Sept.	
Black Cohosh (*Cimicifuga racemosa*)			x				x			White	May to Sept.	Tall flower stalk
Black-eyed Susan (*Rudbeckia hirta*)			x					x		Yellow	July	
Blue Flag (*Iris versicolor*)			x						x	Purple	June and July	
Bittersweet (*Celestrus scandens*)		x			x			x		Green-white	September	Yellow berries
Bouncing Bet (*Saponaria officinalis*)			x					x		Pink	June to Sept.	
Butter and Eggs (*Linaria vulgaris*) Common toad flax			x					x		Yellow	June to Oct.	
Buttercup (*Ranunculis acres*)			x					x		Yellow	May to Sept.	
Butterfly Weed (*Asclepias tuberosa*)			x					x		Orange	June to Sept.	Sandy places
Cardinal Flower (*Lobelia Cardinalis*)			x						x	Red	July to Sept.	
Chicory (*Cichorium Intybus*)			x					x		Blue	July to Oct.	
Closed Gentian (*Gentiana Andrewsii*)			x						x	Blue	Aug. to Oct.	Rarely white
Corn Cockle—Crown of the Fields (*Licharis Githago*)			x					x		Purple	Summer	
Cranberry Bush, high (*Viburnum Opulus*)			x				x			White	June to Sept.	Berries of different colors
Cranesbill Wild Geranium (*Geranium maculatum*)		x					x	x	x	Pale purple	Spring and summer	
Daisy, field (*Chrysanthemum Lencanthemum*)			x					x		White	May to Nov.	
Dandelion (*Taraxacum Dens-leonis*)			x					x		Yellow	May to Oct.	
Devils Paint Brush—European Hawksweed (*Hieracium auranliacum*)			x					x		Orange	June to Sept.	
Dogbane (*Apocynum androsaemifolium*)			x					x		Pink	June and July	
Dogwood (*Cornus Florida*)	x								x	White	April and June	
Dogwood, Red-stemmed (*Cornus Stolorifera*)									x	White	June and July	White or gray berries
Elderberry (*Sambucus canadensis*)									x	White	June and July	Black berries
Elecampane (*Inula Helenium*)			x						x	Yellow	July and Sept.	Tall
Flea Bane (*Erigeron Philadelphicum*)			x						x	Pink	June to Oct.	
Giant Sunflower (*Helianthus giganteus*)			x					x		Yellow	Aug. to Oct.	Tall
Ground Ivy, Gill (*Nepeta Glechoma*)				x					x		June to Oct.	
Ground Pine (*Lycopodium dendroideum*)				x			x			Evergreen	Evergreen	Hillside in woods
Hawkweed (*Hieracium canadense*)			x					x		Yellow	July to Sept.	

Hollyhock (*Althea rosea*)		x						x		All colors	June to Sept.	Tall for background
Honeysuckle, Trumpet (*Lonicera sempervirens*)				x		x				Orange and yellow	Apr. to Sept.	Trailing vine Hillside fences
Horsemint (*Monarda Fistulosa*)		x						x		Lavender	June to Sept.	
Jerusalem Artichoke (*Helianthus tuberosus*)		x							x	Yellow	Sept. to Oct.	Tall
Joe Pye Weed (*Eupatorium purpureum*)		x							x	Lavender-pink	Aug. and Sept.	Tall
Lobelia, Blue (*Syphilitica*)		x							x	Blue	July to Sept.	
Meadow Rue (*Thalictrum Polyanum*)		x							x	White	July to Sept.	Tall
Moneywort (*Lysimachia Nummularia*)			x						x	Yellow	June to Sept.	
Morning Glory (*Convolvulus Sepium*)			x	x	x			x		Pink	June to Sept.	On fences
Moth Mullein (*Verbascum Blattaria*)		x						x		Yellow	June to Nov.	
Mustard, Black (*Brassica nigra*)		x						x		Yellow	May to Sept.	
Periwinkle, common (*Vinca minor*)			x				x		x	Blue	June to Sept.	
Poison Ivy (*Rhus Taxicodendron*)			x	x							June to Oct.	(Poison)
Pickerel Weed (*Pontederia cordata*)		x							x	Blue	June to Oct.	Swamps
Poke weed (*Phytolacca decandra*)		x						x		White	June to Oct.	Purple berries
Rose, Prairie (*Rosa setigera*)	x			x						Pink	July	Climbing for fence
Rose, wild (*Rosa lucida*)	x								x	Pink	Early summer	
Shad bush (*Amelanchier Canadensis*)	x						x			White	April and May	
Skunk Cabbage (*Symplocarpus foetidus*)		x							x		Feb. to Oct.	Large green leaves
Snakeroot, White boneset (*Fupatorum ageratoides*)		x							x	White	July to Sept.	
Spearmint (*Mentha viridis*)		x							x		June to Sept.	
Spicebush (common) (*Lindera Bensoin*)	x								x	Yellow	Mar. to May	Red berries
Spikenard (*Aralia racemosa*)		x					x		x		July and Aug.	Reddish brown berries
Sweet Clover, white (*Melilatus Alba*)		x							x	White	June to Sept.	Sunny hillsides
Syringa, Mock Orange (*Philadelphus Coronarius*)	x							x		White	June	(Red berries)
Sumach, Staghorn (*Rhus hirta*)	x							x		White	June	Rough, dry places
Tomato (*Lycopersicum Esculentum*)			x							White	July to Aug.	Red fruit
Travellers Joy—Old Man's Beard—Virgins Bower (*Clematis Virginiana*)				x						White	July to Oct.	Vine for fences
Tree of Heaven—Chinese Sumac (*Ailanthus glandulosus*)	x									Greenish white	May and June	
Turtle Head (*Chelone Glabra*)		x							x	White-pink	June to Sept.	Sometimes called closed white gentian
Vipers Bugloss (*Echium Vulgare*)		x						x		Blue	June to July	
Woodbine (*Ampelopsis quinquefolia*)			x	x	x						May to Oct.	
Virginia Creeper (*Ampelopsis Veitchii*)					x						May to Oct.	
Wild Lupine (*Lupinus peremus*)		x						x		Purplish blue	May and June	

flowers, some Black-eyed Susan (*Rudbeckia hirta*) for July and any of the local wild asters for the fall, and we have a practically self-maintaining garden of continuous beauty, inconspicuous because it is like the general landscape, yet adorning an otherwise unattractive engineering structure.

This principle can be applied to any other type of ground. Fill the corners and unused spaces with herbaceous plants, backed with shrubbery and small trees. Go as far as you like in planning, in diversification for continuous interest, and even to the collection and babying of the rarer and more difficult things, such as lady-slipper, but as long as the planting is natural and wild, it can be left to itself and will serve the purpose of concealing and beautifying without advertising the grounds.

My good friend, Mr. John M. Skinner, after listening to these rather sketchy remarks, sought the assistance of Mrs. Skinner, to whom we are indebted for the really helpful part of this discussion, the tabulation of wild plants and their characteristics, which follows. To this list I would add only one group that has no flowers at all—the ferns. These are most decorative while always natural, and excellent use can be made of them in many ways.

Sewage Works Cross-Connections*

BY LEWIS S. FINCH

Chief Engineer, Indiana State Board of Health

During the past decade much has been said regarding the health hazards involved in the cross-connection of piping carrying drinking water with other piping carrying water of dangerous or unknown quality.

Wolman and Gorman[1] have shown that many typhoid fever epidemics have occurred in the United States during the past 12 years because unfit water was accidentally pumped into drinking water lines through connections between a safe and an unsafe water supply system.

Groeniger,[2] Connolly,[3] Morris[4] and others have pointed out the possibility of back flow of sewage and other waste water from plumbing fixtures into water supplies.

The possibility of improper connections, which would permit of the back flow of sewage from a sewage treatment plant into drinking water lines, has been recognized, but comparatively little attention has been given to the specific possibilities of such connections.

A recent occurrence at the sewage plant of a state institution in Indiana has served to bring the danger and relatively frequent occurrence of sewage works cross-connections to the attention of the writer. In this case, while there was no physical connection whatever between the drinking water system and any pipe line carrying sewage or sludge, nevertheless, much to the surprise of the sewage plant operator, upon turning on the drinking water tap at the laboratory sink to draw some water, he drew sewage instead. Investigation revealed that water had been left running in a hose line used for washing down the walls of the Imhoff tank and that the end of this hose had by some mischance fallen through the gas vent and into the sludge compartment of the tank. Before this was discovered the water supply to the sewage plant was turned off to repair a valve. It was while the water was turned off that the plant operator started to draw some water at the laboratory tap. The drawing of this water started the sludge to siphon back from the sludge hopper into the water line. Fortunately, the sewage plant was on a dead end and no services other than those of the plant were affected. If this had not occurred on a dead end the result could well have been disastrous.

Undoubtedly such an occurrence will be rare, yet a similar accident might occur at any time on many water supply lines in sewage plants. It cannot be said in this case that the operator was careless or ignorant, for most any one might drop a hose into a gas vent without realizing the possible chain of circumstances that might be set up.

* *Presented before the Joint Meeting of the Illinois Association of Sanitary Districts and the Central States Sewage Works Association, Rockford, Illinois, May 13, 1932.*

A type of cross-connection which undoubtedly exists in many plants is that between a water supply line and the flushing ring in the sludge hopper of an Imhoff tank. If there is such a connection and a water shut-off or sudden demand creates a negative head in the water line while the connection is open, sludge could be siphoned out of the tank in the same manner as in the case of the hose line described above.

Connections to be used for flushing out sludge lines with water under pressure are also objectionable since, if the right set of circumstances should arise, sewage could be taken into the water lines. A set of plans was recently reviewed by the writer in which there was a two and one-half inch water line tapped into both the suction and discharge line of a sludge pump. By opening two valves and closing another, sludge could have been circulated at will through this water supply pipe. It was also within the range of possibility that, due to a sudden demand upon the water line, either a negative or a lowered head would be created and sludge be drawn into the water line without the water being valved off.

Morris, of Pasadena,[4] reports a case of contamination occurring by use of a drinking water supply to prime a sewage pump through the bleeder on the case of the pump. The hazards involved in maintaining such a connection are obvious.

A direct priming connection on the suction side of a sewage pump might not present quite such an obvious picture but, when the possibility of negative or extremely low water pressures is considered, it can be seen that even such an indirect connection may be dangerous.

Undoubtedly there are a number of other possible and even common types of sewage works cross-connections but no attempt will be made in this discussion to canvass the entire field.

Protective Measures

If the health of sewage plant operators and that of the public at large is to be protected, it is obvious that a survey should be made of all sewage plants by the sewage plant operator and by health authorities, for the purpose of finding and eliminating cross-connections through which sewage might find its way into a drinking water system.

Having found the connections it undoubtedly will be possible, although in many cases the proper solution may not be obvious, to take safety measures which will prevent back flow of sewage.

So far as priming pumps are concerned, if a small head tank supplied with city water above the overflow line is used for supplying priming water, the possibility of the back flow of sewage will be obviated. Sludge lines could be flushed in the same manner if pressure were desired. Otherwise, water could be run into the sludge lines directly but with an open connection.

Temporary hose connections could be used between water lines and

connections to flushing rings, if an "air break" fitting were used on the "would-be siphon." In fact, it would appear to be on the side of safety to use such an "air break" fitting upon all risers or hydrants where there would be the possibility of a hose being connected and allowed to fall into a sewage tank.

References

[1] Wolman and Gorman, "The Significance of Water Borne Typhoid Fever Out-Breaks," Williams and Wilkins, 1931.

[2] Wm. C. Groeniger, "Cross-Connections." Paper presented at annual convention of the American Society of Sanitary Engineering, Detroit, September 3, 1929.

[3] Joel I. Connolly, "Private Cross-Connections and Similar Menaces to Public Water Supply Quality," *Journal of American Water Works Association*, **23**, 495 (1931).

[4] Samuel B. Morris, "Cross-Connections with Public Water Supplies," Paper presented at annual convention of the American Water Works Association, Memphis, May 4, 1932.

Destruction of Organic Solids in Sewage by Separate Sludge Digestion*

BY WILLIAM ROGERS COPELAND

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Organic solids, such as are removed from sewage by coarse or fine screens and in settling basins, are often placed in tanks to allow them to rot or digest.

These solids are usually composed of: about 40 per cent of fats and oils; about 10 per cent of cellulose (paper and garbage); about 35 per cent of proteins; about 15 per cent of mineral matter and water.

When such materials are placed in tanks containing a sufficient amount of sludge that has already been partially decomposed by fermentation, due to bacteria and their enzymes, the fresh or "green sludge" will undergo decomposition if the conditions that exist in the tank are favorable.

Many of the fats and oils decompose readily with the formation of carbonic acid and fatty acids, which have an acid reaction. Therefore, the digestion of fats causes the pH (or reaction) of the sludge to drop from the neutral point of 7.0 to 5.0, or even lower.

A pH value of 5.0, though not low enough to kill most of the bacteria of fermentation, is low enough to retard their activity. Such acidity may prolong digestion to 200 days at 70° F. It will still further prolong the time at 50° F., a common temperature for sewage in winter.

Therefore, at low temperatures and low pH values, sludges accumulate rapidly in digestion tanks, thereby setting the stage for a great "blow up" when the warm temperature of summer and summer sewage start the sluggish organisms to renewed activity.

The proteins also undergo decomposition and give off ammonia —(—NH_3—)—. This is a strong alkali that combines with the carbonic acid, fatty acids and similar compounds, thereby raising the pH slowly until it gets to the neutral point at pH 7.0 or above. At this "optimum" reaction digestion proceeds rapidly and great volumes of gas are given off. For that reason the mass of "undigested sludge" may rise to the top of the liquor and form there thick layers of scum.

If, however, the "green sludge" is introduced daily in small doses into a large volume of well-digested ripe sludge, containing, say, 2000 parts per million of ammonia, the acids set free by digestion of the fresh sludge will be neutralized as they form, the pH will be kept at 7.0 or above, and "scum" formation will be reduced to a minimum.

Consequently "ripe sludge" is an excellent agent for regulating pH.

* *Presented before the Fourth Annual Meeting of the New England Sewage Works Association, Boston, Mass., April 25, 1932.*

In the absence of ammonia or other alkaline compounds favorable conditions for digestion of sludge without formation of excessive scum blankets can be obtained by daily additions of comparatively small amounts of quicklime to the green sludge as it enters the digestion tank. Commercial hydrate of lime may be used in powdered form, or better the lime may be mixed with water to form a "slurry" and this run in by measured volume. In all cases the feed should be controlled by frequent pH tests to avoid over-liming.

If the reaction is not corrected often masses of acid or "sour" sludge will gather in the tank. This condition may call for heavy doses of lime at large expense and is sure to result in excessive foaming.

Temperature is also an important factor in sludge digestion.

	40–50° F.	65–70° F.	80–85° F.	100–125° F.
No. of days required for digestion at pH of 6.8–7.6	200–300	90–120	30–50	5–15

NOTE—Some laboratory tests have indicated that at temperatures above 130° F. the period of digestion may be reduced to 24 hours, but this has not been confirmed on any "plant size" scale and the thermophilic bacteria which are responsible for carrying digestion on at such high temperatures are subject to frequent upsets that put them out of commission for days.

The amount of sludge storage space required is also very largely decreased by controlling the pH and temperature to the point of optimum digestion. To store an acid, cold and slowly digesting sludge, the sewage works operator must have from 5 to 7 cubic feet of space per capita, whereas at a pH of 7.0 to 7.4 and temperatures from 80° to 85° F. the space can be reduced to between 1.5 and 2.0 cubic feet per capita.

Recirculation of a liquid portion of "ripe" or well-digested sludge and thorough mixing with the "green" sludge are important aids to good digestion. This can be done simply and efficiently by installing a "plunger" type of pump with the suction set at a point where it will draw liquid from a layer just above the "ripe" sludge (pH 7.0–7.4) and discharge it into the stream of green sludge as this enters the digestion tank. It has been found by experience that at least one volume of such ripe sludge should be added to every two volumes of green sludge.

Folsom State Prison Sewage Treatment Works*

First Four Months of Operation

BY L. E. RUSHTON

Assistant Mechanical Engineer, California State Department of Public Works

The sewage treatment plant at Folsom State Prison, California, is located on the bank of the south fork of the American River. The final effluent is discharged into that river approximately one mile above the town of Folsom. The plant was designed for a population of 4000, an average daily flow of 550,000 gallons and a 12-hour day flow of 730,000 gallons, these quantities being based on flow measurements.

The plant (Figure 1) includes manually cleaned bar screens, in duplicate; grit tanks, in duplicate, with oil skimming weirs; preliminary settling in one clarifier tank; separate sludge digestion without stirring mechanism; gas collection and burning for water heating; mechanical aeration; settling of activated sludge in one clarifier; thickening of fresh sludge and of excess sludge; provision for reaeration; sludge drying on sand beds; and chlorination of final effluent. Also there is a pump house which contains sludge pumps, water heating boiler, incinerator for screenings, office and laboratory.

Primary Clarifier.—The preliminary settling is done in one 36-foot diameter cross-flow tank with a water depth of 7 feet. The average daily flow for the first half of May, 1932, has been 450,000 gallons, with a few days at 600,000. At the 450,000-gallon rate, the ratio of flow to settler surface is 440 gallons per square foot per day and tests have shown approximately 87 per cent removal of solids. The settled sludge was pumped directly to digester during the first two months of operation. Then the thickening of the fresh sludge and of the excess sludge was begun, the overflow from the digester returning slowly to the preliminary settler after being collected in a surge tank. The primary clarifier has a Hardinge mechanism with skimmer. This primary clarifier influent now has a B. O. D. of 175 p. p. m., based on composite samples taken every five days.

Secondary Clarifier.—The secondary clarifier consists of one 36-foot diameter tank with a 12-foot water depth. This is a cross-flow tank with inlet and outlet weirs approximately 25 feet long. This tank also has a Hardinge mechanism operated continuously. One return-sludge pump is run continuously, returning approximately 20 per cent of the average daily flow. Until April 1, 1932, this sludge was discharged to the settled sewage ahead of the aerators. After that date the sludge was reaerated in

* *Presented before the 1932 Spring Conference of the California Sewage Works Association, Yosemite Park, May 20, 1932.*

the first aerator in an effort to improve its quality, but there was little apparent benefit. D. O. now runs from 0.9 p. p. m. at 9:00 A.M. to 1.4 p. p. m. at 2:00 P.M. The B. O. D. averages 10.5 p. p. m. The turbidity is

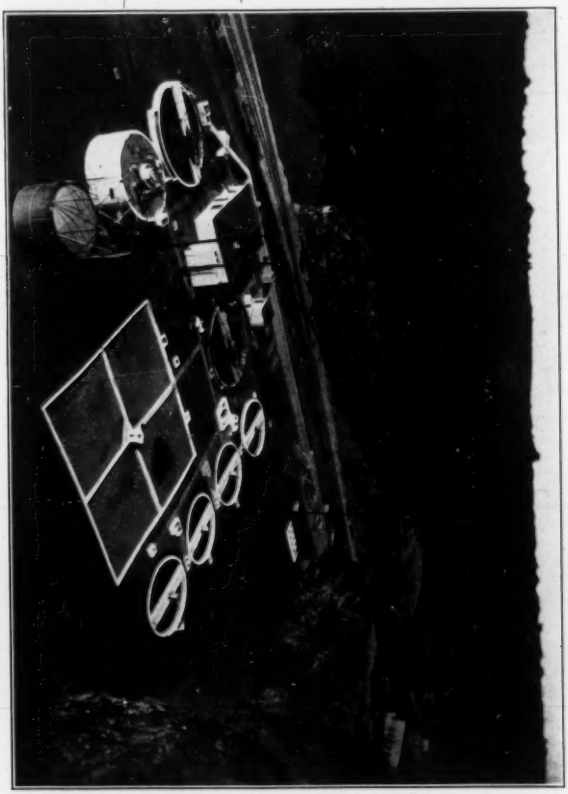

FIG. 1.—Folsom State Prison, Sewage Treatment Works. Preliminary Clarifier, Heated Digester and Gas Holder to Left, Four Mechanical Aerators to Right, Final Settling Tank and Sludge Beds in Center, American River in Background.

approximately 7 p. p. m. and has run in the neighborhood of 15 p. p. m. on various occasions. The percentage of activated sludge runs from 32 per cent at 9:00 A.M. to 45 per cent at 2:00 P.M. The stability normally runs better than 10 days at the present time, as it has done for several weeks.

Digester.—The digester is circular in shape, with a conical bottom, concrete dome cover and a gas collector delivering gas to a 3000 cu. ft. steel gas holder. There are two adjustable overflow pipes, so that overflow can be taken from any selected level down to 10 feet below normal high water level in the tank. This tank has a volume of 9000 cu. ft. or 2.25 cu. ft. per capita. A pipe coil of chrome-nickel-iron cast pipe, for hot water, heats the digester. The temperature has normally been kept at 25° C. by use of the gas produced, which has averaged 1500 cu. ft. per day.

Up to May 11, 1932, sludge in the digester has been so decidedly acid and the settling so poor, that undue load has been put on the aeration end

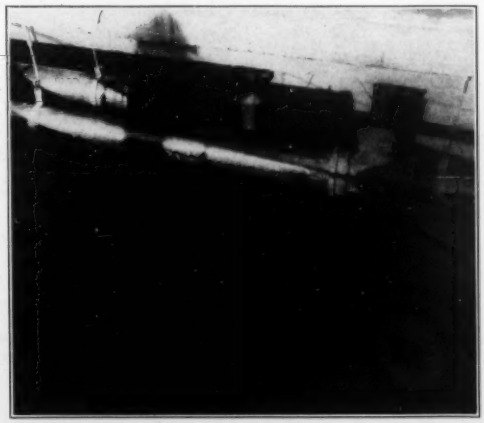

FIG. 2.—Folsom State Prison, Sewage Treatment Works. Interior View of an Aerator, Showing Pump, Pump Column and Radial Discharge Ducts.

of the plant. During March and April, considerable sludge was applied to the drying beds. A volume of 3300 cu. ft. of wet sludge has been disposed of to date. Some of this sludge dried well but most of it, after being sufficiently dewatered to be handled, was buried to remove the odor nuisance. All of this sludge is now fertilizing gardens in the vicinity of the plant. These gardens are operated by convicts and the crops produced are valued highly by these men for they are both producers and consumers.

On May 11, 1932, half a ton of lime was put into the digester and the contents of the tank were circulated by pumping. After one day the pH was and has since remained at 7.6. At this time the digester overflow was

diverted for independent disposal, and not returned to the sewage flow. This change was most likely partly responsible for the improved condition. This diversion of the overflow liquor, however, is only temporary. The activated sludge at this same time has a pH value of 6.6. Of course, the plant operators are hoping this improved condition can be maintained, until the normal aeration effectiveness, with its normal power requirements can be determined. The sludge settled readily after this lime treatment and the overflow is fairly clear black liquor.

Aerators.—There are four circular aeration tanks, each with a volume of 7374 cu. ft., designed for a theoretical retention of 6 hours of the average

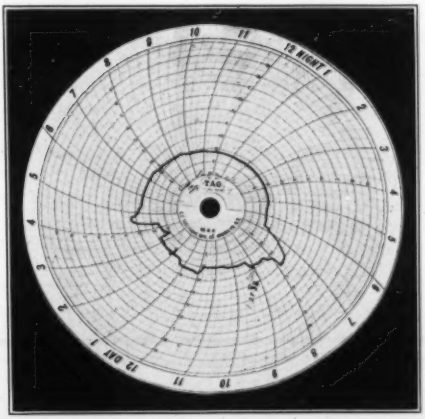

FIG. 3.—Folsom State Prison, Sewage Treatment Works.
Typical Flow Chart for Twenty-Four Hour Period.

12-hour day flow or 8 hours of the average daily flow (Figure 2). These tanks have a water depth of 14 feet 6 inches and are equipped with Hardinge aerator units. Any one of the tanks can be bypassed by the piping arrangement and one of the tanks can be used for reaeration. Since the improvement in the sludge condition due to the lime treatment of May 11, one aerator has been used for reaeration and two others for straight aeration. Since that time the daily flow has averaged 569,000 gallons and the kw. hr. power consumption for successful aeration has averaged 430 or 755 kw. hr. per m. g. treated. During one of the most recent days of high flow, however, a flow of 607,000 gallons was effectively treated with a power consumption of 430 kw. hr. or 698 kw. hr. per million gallons

treated. This is equivalent to a load of 39 hp. per million gallons treated. The retention in this case was 5.3 hours of a flow which is 116 per cent of the average 12-hour day flow rate (6 A.M. to 6 P.M), the returned sludge being 16 per cent.

Special Operating Problems.—The outstanding condition which has apparently delayed the determination of a definite operating schedule has been the greatly fluctuating sewage flow which would become abnormally high or have peaks of long duration on most any day (Figure 3). The cause for this has been attributed to a turbulent water supply along with little or no water clarification. This causes flush valves to stick open. Recently (about May 1) this condition was greatly relieved by using a reservoir for settling all water before reaching the service pipe lines. If you will imagine 900 prison cells in service, each with two occupants and each cell with plumbing and with all the occupants leaving their cells and returning to them about the same time, you can easily picture the flood that is potential whenever a number of flush valves are loaded with grit and ready to stick open.

Another condition which requires special attention is the frequent cleaning required at the bar screens. Considerable quantities of rags, parts of clothing, mops, etc., are collected daily. These screens must be watched closely to prevent clogging and overflowing. Rags overflowing and reaching the preliminary settler and sludge pumps will frequently clog the valves and fittings adjacent to pumps.

Recently a large quantity of oil was trapped in the grit tanks and the wisdom of having such an oil trap was demonstrated. Some of us are glad to have these safety devices demonstrated at times to satisfy ourselves that their cost is justified.

The grit tanks are effective in settling beans and grit and a noticeable quantity of such material, along with some grease, is removed daily. I was advised by Mr. Reinke that at the time of some of his visits to the plant, a gold tooth was discovered trying to find its way through the beans and sand in a grit tank closed for cleaning. The tooth was removed and I feel there has been more interest shown in the care of these tanks since that day.

Operating Data.—Daily observations are made by the prison operators on the final clarifier effluent for B. O. D., relative stability, pH, dissolved oxygen, turbidity and residual chlorine. Other data taken daily include pH values of sludge in the digester, also of activated sludge.

The activated-sludge content, temperature of digester, temperature of sewage, sewage flow, quantity of gas burned, temperature of water for heating sludge, power for aeration, quantity of air induced for aeration, quantity of fresh and excess sludge pumped, chlorine used and sludge removed to drying beds are items for daily observation. The more

important data indicating the operating results are plotted daily, forming a chart for each month.

As yet, the tabulation of a complete record of operating data has not been attempted but by this time next year it is hoped the state will have obtained information much more valuable than that contained in this paper today.

This plant is being operated by prisoners, under the direction of Dr. P. C. Day, the prison's physician. All have shown a keen interest in attempting to obtain the best results possible and the operators have been faithful to follow instructions given them. No small amount of time and effort has been put into this plant by the State Board of Health, Division of Sanitary Engineering. That Division does much constructive advisory work of this kind. They need more man-power, however, to do all the research work that should be done at state-owned plants.

Industrial Wastes and Stream Pollution

Practices of Industrial Waste Disposition at Milwaukee*

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A problem of vital interest and importance in sewage treatment and carrier system maintenance, is the disposition of industrial wastes. Practically every community with or without a sewage disposal plant is, at some time or other, confronted with the problem of industrial waste disposal.

This paper deals with the industrial waste problem from the point of view of effect of industrial wastes upon the efficient disposal of sewage and the proper maintenance and operation of the all-important carrier system. To one acquainted with the transportation of sewage and the final purification processes it is quite apparent that certain classes of wastes are a detriment or a nuisance to either or both. Preliminary treatment or removal of these detrimental wastes is therefore necessary.

Milwaukee, with its diversified industry, finds itself in the position of having to transport and treat a sewage, the greater portion of which is industrial. The city is largely a manufacturing center and numbers among its industries almost every type and kind of manufacturing process.

The following are the industries which contribute the greater part of the industrial wastes requiring preliminary treatment. They represent a fair cross-section of the city's industrial enterprises.

1. Steel products industries.
2. Tanneries (leather and fur skin).
3. Packinghouses and allied industries.
4. Brewing industry.
5. Paper manufacturers.
6. Gas and coke plants.
7. Oil industries.
8. Woolen mills.
9. Marble and stone-cutting plants.
10. Acetylene gas manufacturing plants and private installations for acetylene gas manufacture.
11. Uncontrolled home industry.

* *Presented before the Joint Meeting of the Illinois Association of Sanitary Districts and the Central States Sewage Works Association, Rockford, Ill., May 14, 1932.*

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Regulation of Industrial Wastes.—The Sewerage Commission has the power by law to regulate the amount and kind of industrial waste discharged into the public sewer system. Orders for removal of wastes from the sewers, pre-treatment of wastes prior to discharging to the sewers, and all permits for industrial connection to the public sewer system are authorized and issued by the Sewerage Commission.

Industrial Waste Surveys.—Surveys are made of all of the industrial plants. These surveys cover the plant sewer system, its processes and wastes, as well as the sewers in the vicinity of the plant surveyed, and are made by the engineering and chemical staffs of the Sewerage Commission, in coöperation with the various plant managements. Upon completion of the engineering survey, the chemical staff makes a survey to determine whether or not, and to what extent, pre-treatment of the waste is necessary. These surveys are, of course, the essence of efficient industrial waste disposition, and the success of the work hinges on a thorough and complete examination. In order to insure continued and efficient operation of the industrial waste program, frequent check surveys are made of the various plants. Complete data collected on these surveys are kept on file at the sewage plant.

In the event that pre-treatment or removal of a waste is required, it has been the policy of the commission to lend its engineering and laboratory facilities for the purpose of determining the most suitable and efficient means of such pre-treatment or removal. This coöperation between the Sewerage Commission and the various plant managements has assisted materially in maintaining the good-will of industry generally; which is absolutely essential in industrial waste disposal problems.

Standards Adopted for Preliminary Treatment of Industrial Wastes.—The Sewerage Commission, in its disposition of industrial waste problems, has been guided by the following standards with regard to the necessity for removal or pre-treatment of such wastes.

1. Removal, from industrial wastes, of such solids as tend to settle in sewers, restricting flows with the possibility of ultimate stoppage of flows.
2. Removal or pre-treatment of wastes containing active chemical ingredients, which through their activity result in destruction of sewer structures.
3. Removal or pre-treatment of wastes which may be deleterious either to the purification process or the plant structures.
4. Removal from wastes of all free oils, greases, tarry and resinous substances.
5. Removal of wastes from sewers which may by their presence result in injury or death to men engaged in active sewer work.
6. Isolating from sewage such solids as are eliminated in process and later are discharged to the sewer as a means of disposal.

7. Removal of all uncontaminated waters from the general sewage flow, where storm sewers are available.

Discussion of Standards.—In order to discuss the standards for preliminary treatment it will be necessary to cite some of the problems and to discuss briefly the characteristics of the wastes most frequently met with in our surveys. The discussion of the standards will follow the order in which they appear in the preceding paragraph.

1. Practically all industrial wastes contain suspended solids of various kinds. In many of the wastes however, the suspension, being of high specific gravity, tends to settle out. Some few wastes carry coarse fibrous matters and hair. The wastes containing the heavier suspensions must be pre-treated. The form of pre-treatment consists usually of simple settling units, in which the suspended solids are reduced to a minimum. In cases where the suspensions are coarse and hairy, pre-treatment consists of, in most instances, permanent stationary screens. Where the combination of both heavy suspended solids and coarse fibrous or even hairy matter is discharged, a combination of both settling and screening is required.

Wastes carrying suspensions of solids of high specific gravity frequently met with are, for example, the discharges from stone and marble working plants and acetylene gas manufacturing plants. These wastes run normally, when untreated, several thousand parts per million in suspended solids. Suspensions as small as 100 to 200 p. p. m. of solids will settle out in the sewers even at ordinary scouring velocities. It has been found necessary to reduce the suspension almost completely. Sedimentation units serve efficiently for this purpose.

A typical waste and one commonly met with in industrial surveys, containing both heavy specific gravity solids and coarse fibrous matters is the tannery beam-house waste. Our many surveys have shown that this particular waste is very troublesome from the standpoint of deposition in the sewers. The beam-house liquor is high in lime and contains considerable amounts of fleshings and hair. The combination of suspended matters settles quite rapidly at ordinary sewer velocities. This deposit resembles and acts in many respects like a soft mortar containing a binder. The hair and fleshing binder appears to protect the deposit from the ordinary effects of sewage-flow scouring.

The reduction of the suspended matters was accomplished in three ways. Many of the tanneries, at the time our first surveys were made, used in their beam-house liquors a low grade of lump lime. This lump lime contained, perhaps, between 60 to 80 per cent of calcium oxide, the balance being unburned lime, silica and other impurities. In order to reduce the suspended solids in this waste it was suggested that high-grade dehydrated lime replace the lump lime. The use of dehydrated lime reduced the

quantity of heavy suspended solids by eliminating the large amounts of impurities. The second step in the reduction of the suspended matters was the settling of beam-house liquors in the beam-house vats with subsequent removal of the suspended matters to the dump. The third step was the removal of fleshings, hair and hide scraps. This was accomplished by the use of stationary screening installations in the smaller tanneries and in the larger tanneries by continuous rotary screens.

2. One of the wastes which has been a source of much trouble is the waste containing active chemical ingredients. The bulk of this type of waste comes from the steel products manufacturing industry and is known as pickle liquor. Pickle liquor contains a very high percentage of ferrous sulphate (30 to 50 per cent $FeSO_4.7H_2O$ by weight) and free sulphuric acid in amounts varying from 2–6 per cent. Other sources of free acid wastes are the wastes from engraving plants, metal plating works and storage battery manufacturing plants.

In the past several years we have noted that the sewers in the vicinity of the plants discharging these acid wastes show positive evidence of disintegration and, in one or two instances, sewer structures have been completely destroyed.

Pre-treatment of some of these wastes may be accomplished by neutralization of the acidity. In other acid wastes, when neutralization is impractical, it is necessary to remove the wastes from the sewers completely.

3 and 4. There are many types of wastes which might be considered deleterious to the purification process or perhaps to the plant structures. Obviously, acid wastes in quantities so large as to create an acid condition in the plant conduits and basins would have a destructive action on the plant equipment and structures.

The wastes that, from the standpoint of plant operation, are most damaging, and from any standpoint are a nuisance and a source of great expense are the oil, grease or tarry wastes. The efficiency of the purification units is very noticeably lowered by the presence of oil in appreciable quantities. On several occasions when, through accident or otherwise, excessive amounts of oil or greasy wastes have reached the plant, the efficiencies, with reference to purification, have dropped far below the standards and these lowered efficiencies have continued for periods of days and sometimes weeks.

Not only do large quantities of oil or greasy wastes lower the purification efficiencies but this lowered efficiency is reflected in increased costs in our conditioning and dewatering units.

Most industries contribute wastes containing oil or greasy matters. In all of the plants when there is any likelihood or possibility of oil or grease being discharged, the plants have been required to install efficient

traps. In particular departments of many plants where large quantities of oil are used and where there is always the possibility of much of the oil being wasted, no sewer connections are permitted.

All tarry wastes from producer-gas plants and coke and gas works have been eliminated from the sewers by preliminary treatment. The pre-treatment consists of sedimentation of the tar-laden washings and filtration of the effluent from the sedimentation basins through coke breeze filters.

One of the largest contributors of oils and greases was found to be the automobile drain pits at hundreds of gas stations. In order to insure against the possibility of oil discharge from these pits, the owners were ordered to close all pit drains to the public sewers. The Public Works Department of the city calls, by request, to collect waste oil from any drain pit. Such oils as are collected are stored and used in the incineration of garbage at the municipal garbage incinerator.

It is interesting to note that the growth of the drainpit service which centralized the source of the oil discharges solved a serious problem. It is readily seen that control over private automobile owners draining their own oil is an almost impossible task. With the advent of our present drain pits the problem became one of a controllable industry where the solution was, by comparison, quite simple.

Another source of great quantities of oily, fatty and greasy wastes, in the past, has been the packinghouse and allied industries, such as sausage manufacturers. With few exceptions, these plants had installed grease traps, as the recovery of their grease was quite essential. Our surveys brought out quite clearly the fact that, without exception, large quantities were escaping and being discharged to the sewers. As the grease from these particular industries is marketable, and in normal times its recovery quite profitable, the manufacturers were glad to install adequate grease removal facilities.

Our experience in the past, before complete removal of these greases was practiced, was that not only was the material a nuisance at the sewage plant but that in many instances it resulted in the complete stoppage of the lines through which it flowed.

As an added protection against oils and greases which may enter the plant through the sewage, through faulty operation of pre-treatment units or some other means, scum boards, or floating baffles, have been installed in our grit chamber flow channels. These scum boards serve the purpose of eliminating at least a part of the greases and oils that flow to the plant. Scum boards are not 100 per cent efficient in the removal of oils and greases, but they are, however, some protection. The only reasonably positive method of grease removal is by preliminary treatment at its source.

5. In the present day and age, even though there has been legislation against discharging of volatile oils, gasoline, etc., into the service sewers, quantities of this waste finds it way into them. No doubt the amount of the materials of this character was reduced to a minimum when the waste from the drain pits was eliminated.

6. For many years it has been the practice of some of the industrial plants to dispose of wastes, in the form of solids, which had previously been removed in process and which were in form and condition a refuse for the public dump. However, as a cheap and easy means of disposal the solids were flushed into the sewers. Wet grains and spent hops in the brewing industry, paunch manures in the packing industry, are some of the most common wastes of this type. It is required that these wastes be kept out of the sewers and that they be disposed of in some other manner.

Many wastes of this same character originating in uncontrolled home industries undoubtedly are discharged to the sewers. From the appearance of the material reaching the plant it is evident that the home brewing of wines and beers is a fair example, since tons of waste consisting of grains, grape husks, etc., from these processes enter the plant daily.

7. In line with the preliminary treatment of wastes in various plants comes the disposition of uncontaminated waters discharged into the sewers. In many of the districts of the metropolitan area a separate set of storm sewers is provided. The manufacturers are required to isolate all uncontaminated waters, conductor waters, yard drains, cooler waters, condenser water, etc., and to discharge them to the storm sewers, wherever such sewers are available.

The above discussion briefly outlines the work being done at Milwaukee on industrial wastes. Industrial waste surveys are still in progress and there is still much to be done. While most of the industries contributing wastes have been surveyed and are at present treating their wastes in a preliminary way, still there are many industries yet to be surveyed and new problems confronting us daily.

Industrial Wastes in Relation to Sewage Treatment*

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Preliminary Considerations

Definition of Industrial Wastes.—In the "Definitions of Terms Used in Sewerage and Sewage Disposal Practice, Adopted by the American Society of Civil Engineers and the American Public Health Association," "industrial wastes" are defined as "liquid wastes from industrial processes." They contain dissolved, suspended and colloidal matters, either organic or mineral. Industrial wastes have also been termed "trade wastes," "manufacturing wastes" or "manufactural wastes." In England they are universally called "trade wastes," but the word "trade" has a different significance in this country. In this paper, they are called "wastes" as distinguished from sewage.

Disposal of Wastes.—Industries situated in suburban or rural districts where no public sewers are available discharge their wastes with or without treatment into neighboring streams or bodies of water. In the case of industries located in sewered communities, the wastes are frequently discharged into the sewers either directly or after preliminary treatment. This paper deals only with the discharge of wastes into sewer systems.

Factors in the Discharge of Wastes into Sewer Systems.—The effects of wastes upon the character and composition of sewage depend mainly on the following factors:

1. Physical effects—Temperature, color, turbidity, suspended matters, odor.
2. Chemical effects—Acidity or alkalinity, mineral matter, organic matter, oil and grease, gasoline.
3. Biological effects—Disinfecting action or increase in biological content.
4. Relative quantities of sewage and wastes.

The character and strength of the wastes are important considerations. Obviously the quantity of objectionable wastes from an industry may be so small in proportion to the quantity of sewage that the wastes will have little effect, but if there should be a number of such industries, the combined effect might be serious. On the other hand, unobjectionable wastes, if in relatively large quantity, may overtax the capacity of sewers and treatment plants.

Classification of Wastes.—Because of variations in the wastes produced from similar industries in different places and in the wastes from the

* *Presented before the Fourth Annual Meeting of the New England Sewage Works Association, Boston, Mass., April 25, 1932.*

same industry at different times, it is difficult to classify the wastes from different kinds of industries according to their effects on the sewage. Wastes may be grouped according to their predominating constituents into

1. Organic wastes,
2. Mineral wastes,
3. Combined organic and mineral wastes.

Examples of organic wastes are those from canneries, dairies and packing-houses. Examples of mineral wastes are those from wire mills, plating concerns and paint manufacturing plants. Combined organic and mineral wastes are represented by the wastes from tanneries, textile mills and paper mills.

This classification is subject to many exceptions and does not make it possible to specify the treatment required for each class of wastes prior to discharge into sewer systems. In some industrial plants two or three of these classes of wastes are produced by different processes. In an industrial wastes survey it is generally necessary to give consideration to each individual plant.

Effects of Wastes on Sewers, Pumping Stations and Treatment Plant Structures

Trouble has been experienced from the discharge into sewers of inflammable substances, particularly gasoline, of hot liquids, acid wastes, wastes containing substances which adhere to the walls of sewers and wastes which interfere with the processes of sewage treatment.

Inflammable Wastes.—Gasoline discharged into sewers has been responsible for explosions in various places, blowing manholes into the air, injuring structures, and sometimes resulting in loss of life. Obviously the discharge of inflammable substances into sewers should not be permitted. The importance of controlling the discharge of garage wastes into sewers was dealt with by Mr. Edward Wright in a paper presented before the New England Sewage Works Association at Fitchburg in October, 1930.[1]

Hot Liquids.—Very hot liquids discharged into sewers may cause disintegration of concrete and promote the escape of offensive vapors and gases. At the mills of the Lewis Manufacturing Company in Walpole, Massachusetts, the kier wastes are to be discharged into the trunk sewer connecting with the new Neponset Valley sewer of the Boston South Metropolitan District. These wastes are discharged from the kiers at a temperature as high as 212° F. and are to be cooled to a temperature of 120° F. prior to discharge into the sewer. It is proposed to utilize the heat for furnishing hot water by means of the use of a heat exchanger.

Acid Wastes.—Acid wastes have caused disintegration of sewers at

various places. At Worcester, Massachusetts, in 1897, evidence was found that the concrete invert of the 13 ft. by 18 ft. Mill Brook sewer had been attacked by the acid of pickling liquors from the wire mills, notwithstanding the fact that this sewer received also the entire sewage of the city, then having a population of about 100,000, and the natural flow of a small stream having a dry weather flow of approximately 3 million gallons per day.

At Pawtucket, Rhode Island, a few years ago, it was found that a new concrete sewer was being seriously affected by acid wastes from a wire mill. The company was ordered to keep these wastes out of the sewer or to treat them prior to discharge. Studies indicated that it would be practicable to treat the wastes for the recovery of sulphate of iron.

At Fostoria, Ohio, similar wastes caused corrosion of pumps and disintegration of concrete at the sewage treatment plant. The company discharging these wastes was required to keep them out of the sewers.

The Bureau of Sanitary Engineering of the Maryland State Board of Health, after studies on acid wastes, concluded that a pH of 4.0 is the minimum for plant discharge to assure protection to concrete sewers. This standard has been adopted by the Baltimore City Bureau of Sewers.[2]

Deposit-Forming Wastes.—Deposits in sewers have frequently resulted from the discharge of wastes containing heavy substances, such as sand, lime and carbon, and preliminary sedimentation of such wastes has been required. For example, certain tanneries in the Boston Metropolitan Sewerage Districts are required to provide and operate plants for the removal of objectionable solids before discharging wastes into the sewers.

In the South Essex Sewerage District, trouble has been experienced not only with deposits of hair and lime in the sewer, but a hard coating of carbonate of lime has been formed, seriously limiting the sewer capacity. The solution of this problem, according to Mr. H. W. Clark, Chief Chemist of the Massachusetts State Department of Health, lies in the treatment of the wastes with carbon dioxide, as by passing flue gases through them, to prevent the formation of calcium carbonate.

Grease in wastes discharged into sewers tends to adhere to the walls, resulting in reduced capacity and ultimate clogging. For this reason, grease traps are commonly provided on kitchen drains. Efficient grease traps are particularly necessary in the case of large institutions, hotels, restaurants, etc. Sewers have been completely clogged by wastes from packinghouses where the solids and grease had not been efficiently removed by settling and skimming tanks.

Effects of Wastes on Sewage Treatment

Industrial wastes may greatly increase the suspended solids and organic matter in sewage, as shown by the estimates in the following tabulation:

City	Wastes	Percentage Increase Over Normal Composition of Sewage: Suspended Solids	Oxygen Consumed
Chicago packinghouse district	Packinghouse	460	225
Gloversville, N. Y.	Tannery	155	115
Akron, O.	Rubber-reclaiming	120	140
Fostoria, O.	Wire mill wastes and wastes from carbon grinding	75	100*
Milwaukee, section containing packinghouses and tanneries	Packinghouse and tannery	70	10
Forth Worth, Tex.	Packinghouse	65	...
Dayton, O.	Paper mill	60	25

* Due largely to ferrous iron.

In these cases the wastes discharged into the sewers were equivalent to increasing the population from 60 to 460 per cent, based on suspended solids, and from 10 to 225 per cent, based on organic matter as measured by oxygen consumed. Such increments of wastes add greatly to the load upon sewage treatment plants and correspondingly increase the cost of treatment. Moreover, some wastes such as acid pickling liquors, if in sufficient quantity, may render biological processes of sewage treatment ineffective.

In numerous cases, where the quantity of wastes admitted to the sewer system has been large in proportion to the sewage flow, serious difficulties have occurred in the treatment of the sewage. A few examples of the effects of wastes on sewage treatment are cited below:

Waste Grease and Oils.—At Hudson, Massachusetts,[3] grease from wool-scouring wastes discharged into the sewers caused sand filters to clog so quickly that the company was compelled to keep these wastes out of the sewers. Subsequently, the wastes were treated by the acid-cracking process for recovery of grease and then discharged into the stream.

At Akron, Ohio, several years ago, such large quantities of mineral oil appeared on the surface of the Imhoff tanks at the old plant that it was frequently necessary to remove many barrelfuls from the sedimentation compartments in a single day. As a result of this experience and similar experiences elsewhere, skimming-detritus tanks for preliminary treatment of the sewage have been built at Akron, Dayton, Allentown and elsewhere. Such oil interferes with biological processes of sewage treatment and with sludge digestion.

Yeast Wastes.—At Westborough, Massachusetts,[4] some years ago, the presence in the sewage of waste liquors containing yeast and alcohol from the manufacture of yeast interfered with filtration of the sewage,

and the State Board of Health required treatment of these wastes and regulation of the flow prior to discharge into the sewers.

Acid-Iron Wastes.—According to Mr. Roy S. Lanphear, Supervising Chemist of the Sewer Department, Worcester, Massachusetts, precipitation of iron hydroxide by interaction of lime wastes from the tanneries with acid-iron wastes from the wire mills, in the Worcester sewage has at times greatly increased the quantity of sludge to be handled and correspondingly reduced the period available for sludge digestion in the Imhoff tanks.

At Fostoria, Ohio,[5] the precipitation, by oxidation, of iron in acid-iron wastes caused complete clogging of the trickling filters, necessitating the removal and washing of all the broken stone used for filtering material.

Acid-iron wastes in the sewage delivered to the southerly sewage treatment works of Cleveland, Ohio,[6] were causing precipitation of hydroxide of iron in the trickling filters to such an extent that the filters were shut down from September, 1929, to March, 1930, until these wastes were diverted from the sewers.

Acid-iron wastes have also been detrimental to the activated-sludge treatment of sewage at Elyria, Ohio,[7] where they caused clogging of filtros plates, and at Indianapolis,[8] where they had a germicidal effect on biological life.

Carbide Plant Wastes.—At Atlanta, Georgia, carbide plant wastes caused a thick scum to form on the sedimentation compartments of the Imhoff tanks.

At Salem, Ohio, according to the engineer, Mr. F. S. Barckhoff, lime wastes from a carbide plant, which formerly discharged into the city sewer at times, upset the activated-sludge treatment, causing the sludge to bulk, interfering with sedimentation of the activated-sludge solids and rendering the effluent unsatisfactory.

Copper Wastes.—At New Haven, Connecticut, it was found that the wastes from copper wire works and other copper-working establishments discharged into the sewers precluded the use of the activated-sludge process for the treatment of sewage.

Wastes from Paint Manufacturing.—At the Calumet sewage treatment works of the Chicago Sanitary District, according to Dr. F. W. Mohlman, Chief Chemist, the wastes from a paint manufacturing plant, containing copper, arsenic and lead compounds, until controlled, interfered seriously with the operation of the activated-sludge plant.

Rubber Reclaiming Wastes.—At Akron, Ohio, the wastes from the rubber-reclaiming plants were found to contain more suspended solids than the sewage from the entire city. In accordance with the instructions from the city officials, the new Imhoff tank-trickling filter plant was designed on the basis of the removal of a large percentage of these solids by

the plants before discharging these wastes into the city sewers. This was not accomplished prior to putting the sewage treatment works in operation, thus causing a tremendous overload on the Imhoff tanks, necessitating lagooning of sludge and interfering with the operation of the trickling filters. Considerable progress has now been made by the rubber reclaiming plants in the removal of suspended solids from these wastes.

Tannery Wastes.—At Gloversville, New York, the sewage contained such a large quantity of tannery wastes that a sewage experiment station was operated there some years ago before designing the sewage treatment works. This sewage was found to be much stronger than ordinary sewage, particularly in suspended solids, principally hair and lime. The tanneries were required to build and operate tanks for the removal of excessive quantities of solids.

Felt Wastes.—At Kitchener, Ontario, according to Dr. George G. Nasmith, Consulting Engineer of Toronto, the presence of fibrous material in the wastes from wool and felt plants and tanneries have caused a heavy matted scum to form in the separate sludge-digestion tanks which has to be removed by hand.

Cannery Wastes.—In the village of Holley, New York,[9] the wastes from canneries discharging into the sewers increased the B. O. D. (biochemical oxygen demand) of the sewage to approximately eight times that of domestic sewage, correspondingly increasing the load on the sewage treatment plant.

Packinghouse Wastes.—At Fort Worth, Texas, packinghouse wastes are said to have caused a serious overload on the sewage treatment works, resulting in offensive odors about the plant.

At Chicago,[10] it has been estimated that the wastes from packing houses in 1920 were equivalent in oxygen demand to the sewage from one million people. If and when the wastes from the packinghouse district are treated with the sewage, they will exert a controlling influence upon the design and operation of the sewage treatment works.

Clean Wash Waters.—At Paterson, New Jersey, the wastes from the silk dyeing mills discharged into the Passaic Valley trunk sewer have a marked effect upon the appearance and composition of the sewage, due mainly to dye liquors and soapy wash waters. However, the chief difficulty has been the discharge of large quantities of comparatively clean wash waters which overtaxed the capacity of the sewer and caused overflows of sewage and wastes to the Passaic River. By diversion of the unobjectionable wastes from the sewers, the sewage flow was reduced to the allotted capacity, the cost of sewage disposal was greatly reduced, the pollution of the river from dry weather overflows was eliminated and the river improved during low stream flow by the water diverted from the sewer.

Laws and Regulations Relative to Discharge of Wastes into Sewers

It is generally a wise policy to admit to the sewer system organic wastes requiring treatment, after such preliminary treatment as may be needed to prevent an undue burden of expense for sewage treatment, and to exclude wastes which might injuriously affect the sewers, pumping stations or treatment plant structures or interfere with the treatment processes. Large quantities of waste waters requiring no treatment should also be excluded, as far as practicable.

The laws of some states make provision for the protection of sewerage works either directly or through enabling legislation.

Section 7 of Chapter 83 of the General Laws of Massachusetts makes the following provision:

> If said department (Department of Health) determines after investigation that the unsatisfactory operation of a sewage disposal system is due wholly or partly to the discharge into the system of manufacturing waste or other substances of such character as to interfere with the efficient operation of said works, it may if necessary prohibit the entrance of such waste or other material, or may regulate the entrance thereof into the system, or may require the treatment of such waste or other material in such manner as may be necessary to prevent its interference with the operation of the works.

It is much easier to prevent the admission to the sewers of harmful wastes than to secure their diversion from the sewers after they have been admitted. Section 10 of Chapter 83 of the Massachusetts General Laws provides as follows:

> The aldermen of a city or the sewer commissioners, selectment or road commissioners of a town may make necessary regulations regarding the use of common sewers to prevent the entrance or discharge therein of any substance which may tend to interfere with the flow of sewage or the proper operation of the sewerage system or disposal works....

Many cities have passed ordinances for the protection of sewer systems. The City Ordinances of Worcester stipulate as follows:

> No person shall throw into any drain or sewer, inlet, manhole or catchbasin, any earth, dirt, stones, bricks, sawdust, ashes, cinders, shavings, hair, oyster, lobster or clam shells, or any other substance detrimental to the sewers or the use thereof. (Section 19, Chapter XXXIV)

These Ordinances also provide:

> No live, exhaust or waste steam and no water of a temperature above 140° F. shall be discharged into the public sewers or into any drain connected with them.... (Section 11, Chapter XXXIV)

The original contract between the municipalities in the Passaic Valley Sewerage District and the Passaic Village Sewerage Commissioners dated May 15, 1911, excludes:

> ... all waste from gas works and all substances or discharges which might injuriously affect the integrity of the sewer or sewers when constructed.

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The agreements between the city of Paterson and certain industrial concerns across the river from Paterson for discharge into the Paterson sewer system and Passaic Valley trunk sewer include the following stipulation:

> 9. The Company hereby agrees to comply with all present or future rules and regulations of the City, concerning the character of sewage and trade wastes which may be discharged into the City Sewerage System, and the Company hereby agrees that it will at no time discharge into the sewer any liquids which contain oils, gasoline or any explosive or inflammable materials, or any substances which may be detrimental to or cause disintegration of the sewer structures; or any live steam, or excessively hot liquids; or any other materials which may endanger the life or stability of the sewer structures or which may endanger the life or health of persons within the sewer structures.

In Massachusetts, rules and regulations adopted by the Department of Public Safety with reference to the discharge of inflammable substances into the sewers require the installation and frequent cleaning of certain traps for the separation of oil, gasoline, etc., and the disposal of these substances in a safe manner. Most of the cities and larger towns of the state have adopted plumbing regulations to prevent the discharge of such substances into the sewers. The Sewer Division of the Boston Metropolitan District has established a system of inspection to assure the installation and proper maintenance of the separators at all garages and other places where gasoline is used.

The City of Fostoria, Ohio, following serious trouble at the sewage treatment plant due to industrial wastes, enacted a protective ordinance from which the following excerpts are taken:

> Section 1. That it is deemed necessary for the safe, economical and efficient management and protection of the sewerage system, and sewage pumping, treatment and disposal works, that the emptying . . . of any grease, fats, oils, acids, carbon, iron or mineral wastes, or the wastes from any mercantile, manufacturing or industrial enterprise, other than domestic sewage, which would cause clogging, or which is injurious to said sewers, sewage pumping, treatment or disposal works, or interferes with the proper treatment of domestic sewage, or the operation and maintenance of the sewage disposal works shall be and the said is hereby forbidden and prohibited.
>
> Section 2. That the director of Public Service shall have authority . . . to require any and all . . . industrial establishments . . . to treat all . . . wastes . . . prior to the discharge thereof into the sewers or sewage system of said city, when he deems it necessary for safe, economical and efficient management and protection of the sewage system, and sewage pumping, treatment or disposal works. . . . When such . . . waste plant or device is installed, the degree of treatment shall be satisfactory to the Director of Public Service, and he shall have access to these local treatment plants at all reasonable times for the purpose of inspection and tests . . . whenever such . . . industrial enterprise . . . shall fail to comply with the requirements of the Director of Public Service, they shall forfeit their right to the use of such sewer or sewers, and the Director of Public Service shall forbid and exclude the use of the sewers of said City for the emptying or discharge of such waste therein, until the same is treated according to the requirements and to the satisfaction of the Director of Public Service.

At all municipalities where there are industrial wastes to be disposed of,

prior to admission to the sewers careful consideration should be given to the effects of these wastes upon the sewerage works and upon the treatment and disposal of the sewage, in order that proper protective measures may be taken.

References

[1] SEWAGE WORKS JOURNAL, **3**, 287 (1931).

[2] Annual Report of the State Board of Health of Maryland for the Year Ending December 31, 1930, page 186.

[3] Annual Report of Mass. State Board of Health for 1909, page 125.

[4] *Ibid.*, pages 141 and 387.

[5] Annual Report, Ohio Conference on Sewage Treatment, 1930, p. 30.

[6] *Ibid.*, page 106.

[7] *Ibid.*, page 104.

[8] *Ibid.*, page 116.

[9] SEWAGE WORKS JOURNAL, **3**, 282 (1931).

[10] Report of Engineering Board of Review of the Sanitary District of Chicago, Part III, Appendix I, Sewage Disposal, page 76 (1924).

Rock River Clean-up Program as a Part of Inter-State and National Stream Conservation Activities*

BY ADOLPH KANNEBERG AND L. F. WARRICK

Chairman, Wisconsin State Committee on Water Pollution, and State Sanitary Engineer, Wisconsin State Board of Health

Stream conservation is not a new subject, and requires little by way of introduction. Much attention has in recent years been directed toward the evils resulting from the pollution of our natural waters. There is a growing public insistence that sewage and trade wastes be properly treated before being discharged into our lakes and streams. There is an increasing demand that the public rights and interests in public waters be kept unimpaired or made increasingly useful to man.

As a result of the development of an appreciation of the value of clean waters, various municipal or quasi-municipal, regional, state and federal agencies have been charged with the responsibilities and duties of developing and carrying out programs that have as their objective the elimination of objectionable stream pollution. Typical of these modern agencies coping with pollution problems are municipal sewerage commissions; Sanitary Districts and Metropolitan Sewerage Commissions; Conservancy District Boards; State Sanitary Water Boards, Water Pollution Committees or Commissions, and the United States Public Health Service.

The problem of what constitutes the most beneficial use of our water resources must be determined in general by governmental authority, both State and Federal. Pollution problems affecting two or more states must be solved by interstate agreements or through federal authority, while those of an international character must be taken care of by treaty. Because local authorities usually have a restricted view-point, and are more particularly concerned with some specific problem of a local nature, and because the federal government is not in a position to maintain a sufficiently intimate contact with the numerous problems that arise in a country so diverse in its industries as well as so different in natural characteristics such as rainfall and topography, most of the work of developing and carrying out a comprehensive program of stream conservation must of necessity devolve upon the states.

Many state laws, having as their object the prevention or restriction of pollution have been drafted with a view to taking care of special problems only, and have not sought the establishment of statewide programs for conserving the quality of the surface waters. In recent years, however,

* *Presented before the Joint Meeting of the Illinois Association of Sanitary Districts and Central States Sewage Works Association, Rockford, Illinois, May 13, 1932.*

the trend of legislation has been toward coördinating the activities pertaining to pollution through the creation of special Boards, or Commissions. These groups are frequently made up of state officials representing those departments which are concerned with pollution problems from different angles. Examples are the Sanitary Water Boards of Pennsylvania, North Carolina, and Illinois; the State Stream Pollution Commission of Michigan, and the State Committee on Water Pollution of Wisconsin.

Development in Wisconsin of the State Committee on Water Pollution is at least somewhat characteristic of experiences elsewhere. Laws had been enacted making it a penal offense to discharge trash or other wastes deleterious to fish life into a public lake or stream. In many cases these laws could not be enforced. For example, no economical method for treating the sulphite waste liquor of paper mills was known. The law so far as it affected such paper mill wastes could not be enforced; moreover, the enforcement of the statute was not delegated to a single state agency. The State Board of Health, the Conservation Commission, the various districts, as well as individuals, each had power to institute legal proceedings under the act, with the result that nothing constructive was accomplished. No particular financial provision was made for work involved in bringing about proper disposal of wastes in the prevention of serious conditions in our lakes and streams.

The first step toward correcting these conditions was taken when the Wisconsin legislature in 1925 appropriated $10,000 annually from the conservation fund for stream-pollution control activities. This fund was "to be expended in coöperation with the State Board of Health in a manner agreed upon by the Conservation Commission and the State Health Officer." The activities in the joint program developed during the fall of 1925 and extending until January 1, 1927, are described in a publication entitled "Stream Pollution in Wisconsin," copies of which may be obtained from the Wisconsin State Board of Health.

To further coördinate pollution control activities of various state agencies, the 1927 Wisconsin legislature passed a bill creating a committee on Water Pollution. This committee is composed of the state chief engineer, a member of the Public Service Commission or an employee designated by the commission, a member of the Conservation Commission or one of the employees who may be designated to represent it, the state health officer or a member of the Board of Health designated by the board, and the state sanitary engineer or other engineer appointed by the State Board of Health. The State Board of Health through the Bureau of Sanitary Engineering is the administrative agency. The powers and duties of the committee are set forth in the Wisconsin Waterworks, Sewage and Refuse Disposal Code (1929). Activities and accomplishments to January, 1931, are summarized in the "Progress Report of the State Committee on Water Pollu-

tion." Copies of both of these publications may be obtained from the State Board of Health.

The task before the Committee on Water Pollution is not easy. There are many exceedingly important phases to be considered in both the conception and the development of a constructive stream conservation program. They are technical, legal and economic in their nature, and are so interdependent that none of them may be neglected. A multiplicity of public interests is involved. Benefits derived by controlling the pollution of the waters should be consistent with the general welfare of all these interests.

As an important part of the general policies and procedures developed by the Committee, drainage basin sanitation programs have been inaugurated. Under the plan the drainage areas of major streams in the state are being considered in their entirety from the point of view of stream improvement. The interrelation of pollution situations within such drainage areas is being studied with respect to securing the collective treatment of sewage and wastes and other essential improvements, so as to conserve the quality of the waters and assure the greatest good to all the people.

Each watershed or drainage area presents a different problem, dependent upon the population and its distribution, industrial developments, amounts and character of pollutional wastes, stream flows, topography, climatic conditions and other such factors. It is necessary to consider the uses of the waters, such as for (1) drinking and domestic water supplies; (2) the production of food, including watering of stock, irrigation and commercial fishing; (3) industrial uses, including generation of water or steam power and manufacturing processes; (4) disposal of wastes; (5) navigation and (6) recreation, including bathing, boating and fishing, particularly for game fish. There is also the demand, particularly in areas frequented by tourists, that the natural beauty of lakes and streams remain unimpaired.

Rock River Situation

In view of the dedication of the new sewage treatment plant at Rockford a description of the Rock River sanitation program in Wisconsin will undoubtedly be of interest. The Rock River drainage basin comprises the southern half of a depression that extends from Green Bay and Lake Winnebago in Wisconsin southwestward to the southern limits of the state. The total watershed area of the river above the state line at Beloit is about 3500 square miles not including the Sugar and Pecatonica rivers which join the main stream at Rockton, Illinois. The extreme length and width of the watershed above Beloit is 85 miles and 65 miles, respectively. The low uneven topography has resulted in the formation of an intricate

tributary system with numerous spring-fed lakes. The principal tributaries are the Catfish, Bark, Crawfish, Beaver Dam, and Oconomowoc Rivers. Over one-half of the area is cultivated or used for agricultural purposes. There are water-power developments along the Rock River and its tributaries that have been conducive to the building up of many industrial communities. Sections of the stream have also been more or less extensively developed for recreational purposes, with numerous summer resorts or residences, particularly in the vicinity of tributary lakes.

On the basis of the 1930 census it has been estimated that the total resident population in the Rock River drainage area above Beloit is approximately 300,000. About two-thirds of this population live in 30

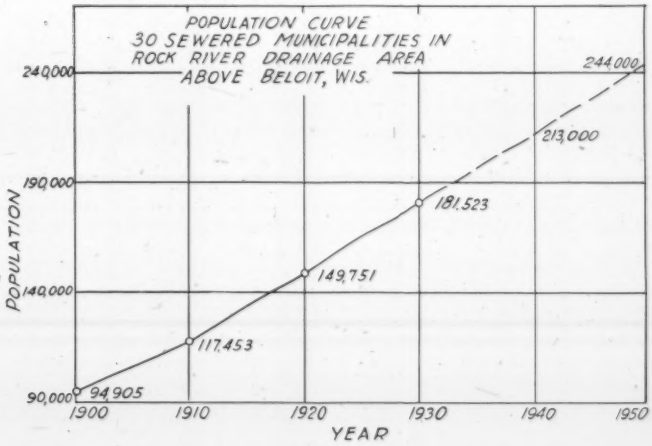

FIG. 1.

municipalities where public sewerage facilities are available. The steady growth in total population of these municipalities is shown in Figure 1. If the growth continues at the same rate, the urban sewered population can be expected to reach 244,000 in 1950. Probable developments of sewerage systems in communities not at present having such facilities will tend to increase this figure.

Until May, 1931, sewage disposal problems in the Rock River drainage area had not been considered collectively with officials of municipalities in the area. Accordingly, a meeting of these officials and others concerned was called by the State Committee on Water Pollution for the purpose of

discussing existing conditions and outlining a general program for reducing sewage pollution of the river and its tributaries to a minimum. The program outlined is essentially as follows:

(1) The preparation of comprehensive sewerage plans and specifications, and estimates of cost where not already available, showing the means and the costs for intercepting sewage at existing outlets and conveying it to a suitable site or sites for treatment and final disposal. These general plans along with detail plans and specifications for the intercepting sewers are to be filed with the State Board of Health not later than July 1, 1932.

(2) The development of a financing program to permit the construction of intercepting sewers and treatment works, either in a single project in certain cases, or in progressive unit projects over a specific period of time. An outline of this program is to be furnished the State Board of Health prior to October 1, 1932.

(3) Provision of at least primary or tank treatment for the sewage in all cases not later than December 31, 1935.

(4) Installation of secondary or further treatment facilities as needed in order to meet local requirements for the abatement of sewage pollution.

Already substantial progress has been made in accordance with this general program, the accomplishments to date being the result of cooperative action.

The status of municipal sewerage treatment in the Rock River drainage area is shown in Figure 2. It will be noted that 9 municipalities with a total population of 72,107 (1930 census) provide complete treatment for their sewage, 14 with a total population of 32,358 provide partial treatment, and 7 with a total population of 77,057 provide no treatment. Under the program outlined at least partial treatment comprising efficient sedimentation for removal of settleable solids is expected within the next few years for all municipal sewage entering the Rock River.

As the sewage interception and treatment problems at Beloit, Wisconsin, and South Beloit, Illinois, can probably most advantageously be taken care of jointly, steps have been taken coöperatively by municipal and state officials to facilitate the carrying out of this interstate sewage treatment project. The necessary preliminary legislation was enacted by both the Illinois and Wisconsin legislatures during the 1931 sessions.

In carrying out these sewage interception and treatment projects municipalities are faced with problems of financing, which in some cases are occasioning study of the possibilities of placing the construction of these sewerage works on a utility basis through the establishment of sewerage service charges. At the present time the Wisconsin statutes include a sewer rental law, but this makes provision for a special fund which may be used only for the operation, maintenance and repair of municipal

sewerage systems. It does not provide for initial construction costs. The placing a small additional charge on water rates for disposal of the

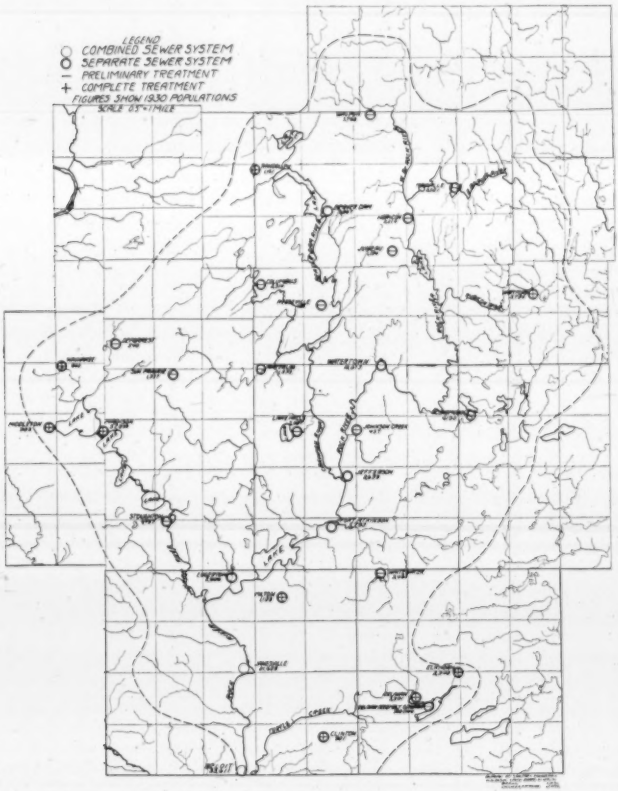

FIG. 2.—Status of Municipal Sewage Treatment in Rock River Drainage Area in Wisconsin.

water after use by the consumers has been suggested as a solution of the financing problem. A legislative bill has been prepared in tentative form looking toward a satisfactory procedure to meet the needs, and to place

the financing procedure in municipalities on the most equitable basis. The Wisconsin legislature will undoubtedly be requested to consider this measure during the 1933 session.

In conclusion, it is believed that the policy of considering pollution situations from the point of view of entire drainage areas, involving such programs as outlined for the Rock River Valley, is sound and will be increasingly followed in the future. It is *further* believed that definite solutions for such interstate problems as may be encountered can best be accomplished through coöperative interstate agreements.

Editorial

Retrospect and Anticipation

A valid criticism of present-day developments in sewage treatment is that the proponents of new schemes and new equipment are not familiar with the history of past cycles of sewage treatment and, in consequence, many schemes are proposed that have been tried and abandoned years ago.

The past year has seen the birth of many proposals for biological and chemical treatment of sewage, some new, some merely variants of established processes. This activity is stimulating and indicates a constructively critical attitude toward the well-established processes of sewage treatment. Scepticism and dissatisfaction of the right kind will usually lead to improvements, but a blanket indictment of all biological processes, or a prediction that our present sewage treatment plants will be scrapped in five or ten years is only destructive and an obstacle to sound progress.

As in the history of social development, so the history of progress in sewage treatment can be traced by the imprint left by leaders of each generation. The decisions of experienced and judicial craftsmen set the course of progress in sewage treatment, just as in other affairs. Therefore it pays to read carefully the words of leading sanitary engineers and chemists who are willing to set down a review of their contacts and experiences in the field of sewage treatment.

With this thought in mind THIS JOURNAL has sought for articles in a retrospective vein from various leading engineers and chemists. Several of these articles have appeared, notably two in this issue, one by George W. Fuller dealing with the problems, past, present and future, of the New York City Region, and one by Langdon Pearse on the problems of the Sanitary District of Chicago. Both of these articles are inspiring in the record of accomplishment and in the preview of future achievement.

Readers should also refer to the article by Harrison P. Eddy in the July, 1930, issue (page 394) on "Massachusetts—the Cradle of Public-Health Engineering" and by Harry W. Clark in the October, 1930, issue (page 561) on "Past and Present Developments in Sewage Disposal and Purification." The dominating influence of Massachusetts on the rise of sewage treatment in America is traced in these articles. A study of the Annual Reports of the Massachusetts State Board of Health and of the Contributions from the Sanitary Research Laboratory of the Massachusetts Institute of Technology should be a requirement of every course in sanitary engineering or

chemistry in our universities. The "golden age" of sewage research in America existed in the 90's and the first decade of the present century, with the names of Sedgwick, Clark, Hazen, Whipple, Fuller, Eddy, Winslow, Phelps and Weston leading all the rest.

In addition to the articles by Clark, Eddy, Fuller and Pearse we have had reviews of the quarter-century experiences of Dr. Hermann Bach in Germany (October, 1931, page 561) and of F. R. O'Shaughnessy in England (January, 1932, page 173). Just recently another English authority, Mr. John D. Watson, has visited America, and those privileged to hear him speak renewed their respect for his achievements in English sewage treatment.

If commercial and inventive sewage specialists would study the history of these men there would be fewer mistakes and fewer failures of promoters or processes. This does not mean that success will be obtained only by looking backward at past achievements. The first requirement for discovery of new things is an imaginative, forward-looking viewpoint, accompanied by a wholesome respect for past achievements. A background of sound experience is essential for evaluation of the true worth of new developments. Inventors and promoters should study and become familiar with the work of unbiased authorities. It may be discovered that so-called new processes were used by and well known to such authorities many years ago. If, however, present conditions warrant a re-study and possibly reuse of processes once discarded, men of experience and unbiased judgment will be quick to take up again the use of such processes or devices.

Proceedings of Local Associations

Pennsylvania Sewage Works Association

Sixth Annual Conference

State College, June 22, 23, 24, 1932

The Sixth Annual Conference of the Pennsylvania Sewage Works Association opened with registrations on the afternoon of June 22, 1932, followed in the evening by a showing of motion pictures by Mr. E. Sherman Chase of Metcalf and Eddy, illustrating modern developments in the treatment of sewage in Europe and America.

The following morning the President of the Association, Lowell W. Monroe, opened the Conference, after which Dean R. L. Sackett, of the School of Engineering at State College, delivered a very happy address of welcome in which he emphasized the important rôle played by the sanitary engineer in our modern social structure.

The first paper upon "Activated Sludge Practice" by Philip B. Streander, Consulting Engineer of Philadelphia, was a very complete summarizing of the principles underlying the several types of activated-sludge plants, illustrated by diagrams. Following Mr. Wellington Donaldson's discussion of this paper, came the interesting "Sludge Digestion Experiences at Baltimore" by Edward Cromwell, Principal Sanitary Chemist of the Bureau of Sewers at Baltimore.

After a business session, A. B. Cameron, Superintendent of the Erie Sewage Treatment Plant, presented a paper describing these large, mechanized primary treatment works recently placed in operation and referred to certain difficulties incurred at the mechanical screens due to bed springs, barrels, harness and other little knick-knacks brought down by the combined sewers of the city. His paper was ably discussed by John T. Campbell of the J. N. Chester Engineers, designers of the Erie plant, after which George W. Jones, Chemist, U. S. Bureau of Mines, Pittsburgh, presented a particularly timely and interesting paper dealing with the mechanism of explosions and the hazards arising from the gases to be found at modern sewage treatment plants, including a consideration of oxygen deficiencies.

L. S. Morgan, District Engineer, Pennsylvania Department of Health, then gave a clear presentation of "What the Pennsylvania Department of Health Expects of Each Operator," outlining the principles underlying

each unit of the treatment plant and the points to be observed by the operator in maintaining each unit at best efficiency. He also emphasized the necessity of adequate records which should be kept at all properly operated treatment works.

Mr. Isaac S. Walker, Consulting Engineer of Philadelphia, discussed the function of each unit of a sewage treatment works and gave most practicable suggestions upon the duties of operators in connection with such units.

The annual dinner was held at the Nittany Lion Inn in the evening and after a brief round table discussion of difficult operating problems, developed into a surprise entertainment at the hands of a master magician, Harry Alpigini.

Friday morning was given over to papers upon plant operation, the first one being upon "How to Start a New Sewage Plant," by Harry M. Beaumont, Assistant Engineer, Bureau of Engineering and Surveys, Philadelphia, who gave some results of his many years of practical experience. This was followed by "Insect Control," by J. W. Simpson, Supervisor of Sewage Plants of Reading, who outlined his methods for controlling the psychoda and other regular attendants at filter plants, after which R. R. Cleland, Engineer of the Sewage Disposal Plant at State College, dealt in an interesting manner with "Winter Operations," including the ever-present sludge problem. "Control of Odors," by W. A. Ryan, Chemist of Rochester, New York, "What Constitutes an Acceptable Effluent," by William C. Emigh, City Engineer of Coatesville, Pa., and "Laboratory Control," by Michael J. Blew, Assistant Engineer, Northeast Sewage Treatment Plant, Philadelphia, were all distinctly practical papers of real interest and value to operators.

In spite of this year of depression, 106 registered for the conference and 95 attended the banquet; the association membership was 111 prior to the conference and 125 at the close.

The following officers were elected: *President*, R. O'Donnell, State College, Pa.; *First Vice-President*, Harry Krum, Allentown, Pa.; *Second Vice-President*, R. L. Phillips, Meadville, Pa.; *Secretary-Treasurer*, L. D. Matter, Wilkes-Barre, Pa.; *Editor*, J. R. Hoffert, Harrisburg, Pa.; *Representative to the Board of Control of the Federation of Sewage Works Association*, C. A. Emerson, Jr., Philadelphia, H. E. Moses, Harrisburg, Pa.

Items of business included a discussion of the publication of the papers of the Association; reference to the Executive Committee of a proposal to merge with the Pennsylvania Waterworks Operators' Association; adoption of a registration fee for the annual conference; the request of the Association that the U. S. Bureau of Mines through its Pittsburgh office continue its investigations into the very live subject of the explosion and other hazards of sewage gas; and reference to the Executive Committee of

plans for the licensing of sewage plant operators and for an extension school for the training of such operators.

The next Annual Conference will probably be held at State College in September, 1933, this fall date being necessary because of the meeting of the American Waterworks Association in Chicago from June 12 to 16, 1933.

J. R. HOFFERT, *Editor*

New England Sewage Works Association
Notice of Fall Meeting

The 1932 Fall Meeting of the New England Sewage Works Association will be held October 17, 1932, at the Stratfield Hotel, Bridgeport, Connecticut.

As noted in our May, 1932, issue (page 551) it was voted at the Boston meeting, April 25, 1932, to change the date of the annual meeting from April to October, in order that officers and representatives might take office the following first of January.

F. WELLINGTON GILCREAS, *Secretary-Treasurer*

Reviews and Abstracts

H. W. STREETER

Observations and Experiences in the Design and Construction of a Sewage Purifications Works

By W. H. E. Makepeace

Paper presented at meeting of Manchester District of the Association of Managers of Sewage Disposal Works, April 2, 1932. Résumé, with discussion, in *The Surveyor*, **81**, 395–99 (April 8, 1932)

Abstracted by J. K. Hoskins

The remarks are based on experience and observations of the author concerning sewage treatment works dealing with dry weather flows of from 0.1 to 12 m. g. d. In general the design is influenced by topographical and other local conditions. A site that permits gravity flow throughout the plant is the ideal one. The plant should be located on the windward side of populous districts if possible, otherwise, sludge should be disposed of on a separate site.

General Features of Design.—Foundations should be explored by trial holes and adequate steps taken to avoid subsidence of the structures. Compactness should be a feature because of economy both of construction and maintenance. Consideration should be given to the possibility of housing developments near the works regardless of the original isolation of the site. Special attention to the outfall works design may be necessary to avoid pumping with its imposed operating costs. It is also advisable to record both dry weather and storm flows of the sewage at the outfall, preferably by separate instruments.

Grit Chambers and Screens.—The most efficient grit chamber is one not much wider than the outfall sewer and deep enough to allow deposition of grit. The size should be such as will reduce the velocity sufficiently to drop the mineral matters and carry forward the lighter bodies. In small works grit can be removed by hand; in larger works decanting of the liquor from the chambers is preferable to the use of grabs with the chambers in use. Screens should follow rather than precede grit removal devices. If the screened sewage is pumped, fairly fine grade screens are desirable, otherwise coarse screens are to be preferred.

Sedimentation Tanks.—The inflow to sedimentation tanks should be so arranged as to dissipate as rapidly as possible the energy of the influent liquid. The velocity through the tank should be such as to provide maxi-

mum deposition of suspended solids and at the same time avoid danger of creating serious septic conditions. The most efficient tank is one of rectangular shape with full width weir inlets and outlets. Theoretically, the flow through such a tank would be in a series of parallel lines from inlet to outlet, but this is largely influenced by temperature conditions. The inlet end of rectangular tanks should be the deeper rather than the opposite. The proportion of width to length is of importance as well as is the floor design in which sharp angles should be avoided. Floors should be sloped to facilitate sludge removal.

Upward flow tanks of the inverted pyramid type are satisfactory for domestic sewage following grit removal and for dry weather flow rates where the upward velocity is 4 ft. per hour. When these optimum rates are exceeded the author suspects the efficiency of such tanks is rapidly reduced.

Sludge Disposal.—The sludge pressing method still has many advantages and this procedure should not be scrapped in existing plants except for good reason. Sludge digestion, although popular, demands an abundance of drying area. Experience, especially with the potteries' sludge, shows the dewatering process to be a very slow and inefficient one. Although perhaps somewhat more costly, pressing is at least rapid and positive.

Aeration Plants.—The diffused air method is well suited to the potteries' sewage (Stoke-on-Trent) because of the beneficial effect of the clay particles. Average depth of channels is 7 ft. and short circuiting is prevented by dividing the longitudinal channels into a series of bays formed of hollow walls down which the surface flow of one bay is directed to the bottom of the succeeding one, throughout the length of travel. Pyramidal settlement tanks constructed out of old rectangular tanks are fairly satisfactory.

Storm Water.—Treatment of storm water is important. Where pumping is necessary it is advisable to separate storm water at the pumping station. Recent storm tanks have inlet weirs fixed at varying levels, all below the outlet weirs which are with one exception at a common level.

Bacteria Beds and Humus Tanks.—Preference is now being given to beds deeper than the general 5 or $5\frac{1}{2}$ ft. depth and also to larger size of material. Humus tanks are either of the inverted pyramid or rectangular flat bottomed type depending on local construction circumstances.

Discussion.—In opening the discussion of the paper, Mr. C. H. Ball emphasized many of the points brought out by the author. He did not agree, however, that pressing was the most economical method of dewatering sludge. At Davyhulme pressing had been discarded and the sludge was being applied to land. As soon as the sludge was put on the land it was plowed in and then covered with a special type of disk wheel drawn by a tractor to minimize nuisance.

Mr. T. Barlow suggested the advisability of duplicate grit chambers to provide flexibility of operation during storm flows. He was in agreement with the author's remarks regarding sludge pressing and location of screens following the grit chambers.

Mr. A. R. Ward stated that except where pumping was necessary screens should follow the detritus tanks and that such screens should be inclined rather than vertical. For proper sedimentation in rectangular tanks baffle walls were an advantage though too many baffles reduced the efficiency of settling. The need of more knowledge on the principles of sedimentation in rectangular tanks was emphasized by several speakers.

Mr. J. Slater preferred sludge digestion and drying to pressing because of the greatly reduced cost and ease of handling. He applied sludge to the drying beds to a depth of 18 inches in summer and 14 inches in winter. Humus sludge was returned to the incoming sewage. The formation of scum in the humus tanks was greatly reduced by increasing the times of dosing of the filters and cutting down the quantity applied each time.

Various speakers were of the opinion that the Ministry of Health requirements for rates of flow through detritus tanks were too slow and permitted deposition of organic matter with the grit. A velocity of 0.45 ft. per second was recommended by the author in his closing remarks.

Treatment of Gas Liquor

BY J. HURLEY

Paper presented at Yorkshire District meeting of the Association of Managers of Sewage Disposal Works, Leeds, England, April 9, 1932. Résumé and discussion in *The Surveyor*, **81**, 421–22 (April 15, 1932)

ABSTRACTED BY J. K. HOSKINS

Opinion remains divided concerning the advisability of discharging gas liquor to public sewers and treating this waste along with domestic sewage. Although this may be the most efficient and economical procedure, it remains true that most of the harmful constituents such as phenols of gas liquor have a commercial value which is lost by such treatment and that the addition of strong antiseptics to biological sewage processes is contrary to reason.

The contribution of gas liquor to the biological plant reduces both the volume of sewage that can be treated and the quality of the effluent produced. Thus when the gas liquor amounts to 2 per cent of the total sewage volume, the actual oxygen absorbed figure is increased by about 200 p. p. m. and the final effluent has both a high oxygen absorption and a reddish color. It may be assumed that gas liquor from a works serving

the same population as the sewage works raises the oxygen absorption value of the sewage about 30 p. p. m. If the addition of such liquor is uniform the combined sewage can be treated, and once biological action is well established it can be maintained and in amounts up to 2 per cent does not increase filter clogging.

Comparative Effects of Crude and Spent Liquors on Sewage Purification.—Crude liquors contain about 1400 p. p. m. of sulphides, equivalent to 2000 p. p. m. of oxygen absorbed. Such high sulphur content might cause unsightly growths of *beggiatoa* on the effluent channels, and be a source of nuisance especially if acid liquors are discharged to the sewers or used as a precipitant at the sewage works. Crude liquor does not contain the calcium salts and free lime that are present in spent gas liquors and which are of advantage in precipitating the soaps of the sewage, especially of textile sewage, but, on the other hand, does increase the danger of tar especially from plants making low grade gas. The balance is, therefore, definitely in favor of spent liquors for which the crude liquors cannot be substituted safely in every case.

Experiments at Shipley.—Filtration of strong crude gas liquor through activated carbon at the rate of 500 gallons per cu. yd. per day was tried to partially purify such waste and thereby relieve the load on the sewage works. This rate of dosage, intentionally heavy because of the cost of active carbon, was not satisfactory. The effluent soon had a high oxygen absorbed value and very deep color and the filters clogged, a condition which resting or raking did not remedy. Precipitation of the crude gas liquors by copper sulphate was also considered. Because of the cost of this chemical, recovery of the copper would be essential for practical operation. The method has some merits, however, as the thiocyanates would be largely precipitated, the salts most difficult to oxidize by biological means.

Discussion.—In the discussion of the paper Mr. W. D. Scouller stated that at Huddersfield no effect of the gas wastes contributed to the sewage could be detected except that the ammonia content had increased from 20 to 60 p. p. m. No sulphocyanides had been found although the ratio of the 3 minutes' to the 4 hours' oxygen absorbed value had changed from $^1/_2$ to $^1/_{1.5}$. He suggested that some kind of roughing filters would be more efficient than active carbon because the removal of sulphur was the important thing.

Mr. J. H. Garner stated that the gas liquor at one plant in the West Riding district was entirely disposed of partly by evaporation on the bars of the gas producers and partly in a plant to a consistency where it could be mixed with fuel and burned. He also inquired whether parallel tests had been made of the relative efficiency of treatment of crude and spent liquors mixed with sewage, to which the author replied that no such data

were available. A very large phenol recovery plant working on the active-carbon principle had been in operation in Germany but owing to the present reduced price of phenol it was no longer in use. Regulation of the flow of gas liquor to the sewer was stressed.

Mr. L. Etheridge remarked that the Manchester plant was recovering phenol at a cost just above equal to the value of the by-products but that smaller plants could not hope to do this at current prices. He stated that at Hinckley and at Coventry crude liquor was being disposed of experimentally in the sewage without interrupting purification processes. The only difference between crude and spent liquors was the strength and the presence of sulphide which should not be troublesome. He would anticipate no success with the activated carbon treatment.

Mr. E. Arrowsmith observed that at Swenton the gas liquors are settled in separate tanks and then treated by irrigation on land. Although the land showed no bad effects no attempt has been made to grow crops.

In closing the discussion Mr. Hurley stated that the presence of gas liquor generally increased the suspended solids of the filter effluent and that he had as much sludge in the secondary tanks as in the settling tanks.

Sewage Disposal at Todmorden

BY J. H. LUMB

Résumé in *The Surveyor*, **81**, 515–16 (May 20, 1932) of a paper presented at the Yorkshire district meeting of the Association of Managers of Sewage Disposal Works

ABSTRACTED BY J. K. HOSKINS

The original sewage treatment works of Todmorden, built in 1908, consisted of screens, detritus tanks, storage tanks, chemical precipitation tanks and primary and secondary contact beds. The contact beds having become completely clogged, the works were extended and reconstructed since 1927. The population of Todmorden is approximately 22,000 and contributes about 0.48 m. g. d. of sewage, which with 0.02 m. g. d. of trade waste and 0.6 m. g. d. of subsoil and surface water constitutes the total of 1.1 m. g. d. flow to be treated.

On reaching the works the sewage first passes through duplicate, mechanically cleaned bar screens with $^1/_2$-inch openings. It next flows through one of two detritus tanks, each with a capacity of about $^1/_2$-hour sewage volume. These tanks are cleaned by an automatic traveling dredger with a capacity of $8^1/_2$ cu. yd. per hr., and which delivers the detritus to a cast iron worm conveyor for deposit on a concrete drainage area. Beyond the detritus tanks storm water is diverted to flow to special storm water tanks, 100 × 38 ft. in plan and 5.5 ft. deep. Dry weather

sewage passes to storage or balancing tanks of 1 hour total capacity and thence to the pump well from which it is pumped to the sedimentation tanks.

The eight sedimentation tanks are each 90 × 42 feet in plan and 7 feet deep. The sludge from these tanks is pumped to sludge tanks for pressing or to sludge drying beds as desired. The effluent of the sedimentation tanks passes to percolating filters of a total area of 10,000 sq. yd. which contain 13,850 cu. yd. of $^3/_4$ to $1^1/_2$ inch medium underlaid with tile drains 3 ft. on centers. The filters have solid concrete side walls which permit flooding to reduce fly nuisance. The filters are dosed by traveling distributors.

Secondary sedimentation is provided by 3 tanks, each 117 × 24.5 ft. in plan and 4.5 ft. deep, providing a detention period of 5 hours. Floating arms decant the supernatant water and a sludge pump removes the settled sludge to the drying beds, presses or to the incoming sewage.

Three sludge-drying beds are each 150 × 90 ft. in plan, and each divided into four sections with a distribution chamber in the center. The medium is 2 ft. 3 in. deep graded from $^3/_4$ to $1^1/_2$ inches, with a top dressing of $^3/_4$ inch or less. The four original sludge presses, now used as a standby service, each contain 26 plates 30 inches square and can turn out at each discharge 1250 lb. of pressed cake. The presses are fed and operated by compressed air.

Operating statistics for the entire treatment plant covering a period of one year are given, including costs and typical analyses of the crude, settled and final sewage effluent.

An Investigation of the Occurrence of Bacteriophage in Surface Water

BY PROF. DR. E. GILDEMEISTER AND PROF. DR. HOTORI WATANABE

Gesundh. Ing., **55**, 241 (1932)

ABSTRACTED BY G. P. EDWARDS

Bacteriophage is found in all waters containing fecal pollution. Whether or not they play a part in the self-purification of water is still disputed. In these experiments, water from the river Spree above and in Berlin and from a lake lying southwest of Berlin was used. The water was mixed, as soon as possible after collection, with equal parts of nutrient broth and allowed to incubate at 37° C. until the next day. This turbid broth-water mixture was passed through a Seitz filter and the filtrate was plated out with bacteria on agar. Bacteria of the typhoid, paratyphoid, coli and Ruhr group, isolated from man and animals, were used.

In none of the water samples could bacteriophagic action be detected without incubation, indicating that bacteriophage are not important in the self-purification of river water. In the river Spree, there was a large concentration of bacteriophage after a rain or thaw but only a small amount during dry weather. It was concluded that water from rain or thaw washed fecal pollution from the earth into the river water. There seems to be little direct fecal pollution in the river Spree above or in the City of Berlin. The secondary pollution above Berlin is mainly limited to animal feces. The water of the canals in Berlin always contains bacteriophage but there is an increase after rain or thaw. The lake water, only slightly polluted, contained very little bacteriophage. If a large concentration of bacteriophage is found in a sample, primary contamination can be assumed. Sewage is always rich in bacteriophage.

The bacteriophage detected in water and sewage was mainly active against the bacteria of the Ruhr group and preferably against Shiga bacteria. In waters rich in bacteriophage, bacteria of the typhoid, paratyphoid and coli group were attacked, but in water containing only a few bacteriophage the action was predominantly against the Ruhr bacilli. No bacteriophage active against *cholera vibrio* or *B. abortus Bang* were found.

This determination of bacteriophage is suitable for detecting primary pollution if there has been no rain or thaw for five days before collection of the sample.

Preliminary Experiments to Explain the Self-Purification Processes in Polluted Streams

BY DR. JAN SMIT

Vom Wasser, **5**, 178 (1931)

ABSTRACTED BY G. P. EDWARDS

There is little accurate information available as to the character of the biological processes taking place during the purification of a stream, although we know that there is a reduction in the number and kind of bacteria. The three kinds of bacteria always present in polluted waters are *B. coli*, the gram positive streptococci and *B. enteritidis sporogenes*. The decrease in bacteria is due to sedimentation, light, temperature, chemical composition of the water, competition between the bacteria and the action of bacteriophages and protozoa. The pathogenic organisms, such as *B. typhi* and *para typhi*, disappear first. Then the fecal streptococci, such as the Eijkman-positive, and finally the Eijkman-negative and the other abnormal coli types disappear.

Three types of water, Amsterdam tap water, canal water and pond water from a city park, were sterilized by filtration through a Chamberland-Kerze filter. Sufficient *B. coli communis* were added so that each type contained about 400,000 per cc. and the number of bacteria was then accurately determined. The flasks were kept at uniform temperature in a diffused light. The death rate was lowest in the most polluted water.

The addition of oxygen, nitrogen, hydrogen and carbon dioxide showed that the death rate was greater in the absence of oxygen. The addition of bicarbonate, peptone, urea and ammonium salts favored the survival of the organisms. The addition of nitrate had no effect.

Caramel and sodium humate were used to color two waters containing *B. coli communis*. The caramel solution was free from nitrogen whereas the humate contained 1.3 mg. nitrogen per cc. Although the humate solution increased the oxidizability of the water only slightly, the death rate was retarded.

An experiment showed that a natural water and a synthetic one made to duplicate the natural water have the same effect on the death rate. The influence of other bacteria, such as streptococci and spirochetes, was very small and the addition of a coli bacteriophage increased the death rate only if a large number of coli organisms were present. However, protozoa (*Cyclidium glaucoma*) reduced 6 million organisms to about zero in five days. At 24° C. the organisms died more rapidly than at 4° C.

In water undergoing purification, there are four groups of coli bacteria based on their ability to ferment glucose and lactose at 37° C.

	Glucose 37°	Lactose 37°	Eijkman 45°
Group I	+	+	+
Group II	+	+	−
Group III	+	−	−
Group IV	+	−	+

The organisms of Groups II and III die much faster at room temperature than the normal type when they are placed in sterile pond water. Those of Group IV are somewhat more resistant. With mixtures of the various types, the colonies on endo agar soon lose their metallic sheen and the red color is confined to the colonies alone. Transferring these organisms to lactose broth brings them back to normal. No permanent transition from one group to another was observed.

Comparison of the properties of numerous streptococci from feces, different waters and milk showed that the two groups which predominate are distinguished mainly by their behavior on blood agar and raffinose. From 126 cultures, 65 had no effect on blood agar and 61 had a dissolving action. Of these 61, 54 had no effect on raffinose whereas, of the 65 blood-agar negative organisms, 59 consumed raffinose with acid formation.

The streptococci of milk and polluted water are closely related and both come from feces. The blood-agar negative organisms die in a very short time when placed in sterile water. Although streptococci usually grow best under anaerobic conditions, air and oxygen increased the life period. One would expect these organisms to die quickly in quiet water.

Since *B. coli* live longer than streptococci or typhoid organisms, they are the best indicator of pollution.

The Remodeling and Reconstruction of the Sewerage and Sewage Disposal Works at Southampton

BY S. G. STANTON, Borough Engineer and Surveyor, Southampton

Journal of Royal Sanitary Institute, **52**, 521–32 (June, 1932)

ABSTRACTED BY S. I. ZACK

In 1920, when the boundaries of the borough were extended, plans for remodeling of sewerage and sewage disposal were presented to the Ministry of Health. The work was held up until 1928 when grants from the Unemployment Grants Committee provided means for carrying out the schemes for Southampton drainage and sewage disposal.

The Portswood sewerage and sewage disposal consists of a plant on 13 acres of reclaimed land handling sewage from a "gravitational" and "pumped" system. Storm tanks of 185,000 gallons, or 12-hour capacity, were provided, discharging directly to the river. The existing settling tanks have a capacity of 270,000 gallons, equivalent to 17 hours' dry weather flow, and are followed by 90 ft. diameter sprinkling filters 3 ft. 6 in. deep. The depth of the filters is restricted by the elevation of influent and high tide. Duplicate humus tanks, each of 1-hour detention, dry weather flow, and a tidal tank of $6^1/_2$ hours, peak flow capacity, follow the filters.

The pumped system is an entirely new scheme built on the highest portion of the site and so designed to discharge the effluent at any state of the tide. This plant is designed for 30 gal. per capita per day for a population of 39,600. Dual inverted siphons of 12-inch and 15-inch diameter, respectively, laid with victaulic joints encased in concrete, carry the sewage equal to 3 D. W. F. under the River Itchen. Storm tanks for a part of the flow above the siphons save pumping. Three-quarter-inch screens, one mechanically cleaned, precede the pump well. The sewage is pumped through detritus tanks, from which it flows past two storm tanks to seven continuous flow settlement tanks, each 100 ft. by 30 ft. by $5^1/_2$ ft. deep, designed for 15-hour flow. The storm tanks are designed for $6^1/_2$-hour flow. The tanks are followed by clinker filters 100 ft. diameter

and 6 ft. deep. Humus tanks of 2-hour flow capacity follow the filters. The treated and storm sewage are discharged through a common outfall. Sludges from the gravity and pumped systems are pumped by ejectors to a barge for disposal at sea.

At the Woolston sewage disposal plant, the existing septic tanks were converted to storm tanks, the contact beds changed to settling tanks and the addition of detritus tanks, screens and mechanical grit elevator modernized the works.

The scheme prepared and provisionally approved for the Shirley district drains an area of 2250 acres, equivalent for a population of 150,000. Fourteen tanks, each 100 ft. by 50 ft. by 7 ft. deep, will be required, designed against uplift pressure due to wet ground. Sludge will be disposed of at sea.

The cost of the Shirley Works will be about $710,000 and $410,000 for trunk sewers. Part of the sewage will be diverted to the plant to be remodeled at Corporation Wharf, Chapel.

Saranac Lake's Sewage Treatment Plant

BY HENRY W. TAYLOR

Public Works, **63**, 18–20 (April, 1932)

ABSTRACTED BY H. W. STREETER

Nuisance conditions in the Saranac River caused the City of Saranac Lake, N. Y., to install a sewage treatment plant, which was placed in operation in December, 1931.

The treatment works consist of 3 settling tanks equipped with parallel sludge collectors, sludge digestion tank, sludge storage tank and sludge beds. Each tank is 75 ft. long, 16 ft. wide and 7 ft. deep, giving a retention period of 3.75 hr. for the present 10,000 population, and a velocity of flow about 6 inches per hour. As the bottoms of the settling tanks are 4 ft. below ground water level, the tanks are underdrained, with provision for pumping out ground water, and tees extend through the tank floors, with scuppers which will blow in case the operator should fail to dewater prior to draining a tank unit.

The sludge is blown from the settling tanks to a well, whence it is pumped to a digestion tank provided with a hot water heating system, which is heated by gas obtained from the sludge digestion, with a kerosene burner in reserve. There is also an unheated digestion tank and, between the two tanks, control valves for feeding fresh or digested sludge to any desired unit.

The sludge bed is designed with an area of 1 sq. ft. per capita for a

future population of 14,000. The beds are equipped with industrial tracks and light trucks which can be moved from one track to the other by 2 men.

The cost of the plant proper, as designed for 14,000 people, was less than $50,000, or $4 per capita. The total cost of the project, including the trunk sewer extension, was $138,000, the trunk sewer being designed for a population in excess of 20,000. The total present cost, for 14,000 people, is less than $10 per capita. When additional treatment units have been installed for 20,000 people, the unit cost of the whole project will be about $7.50 per capita.

Amount of Sewage from Schools and Institutions

ANONYMOUS

Public Works, **63**, 29 (March, 1932)

ABSTRACTED BY H. W. STREETER

In a discussion of this question by the Maryland-Delaware Water and Sewerage Association, Dr. Willem Rudolfs stated that during the past year accurate measurements of the sewage flow had been made from two schools, one of about 125 and the other of 240 pupils. The flow was found to vary from 8 to 15 gal. per pupil daily. Measurements of seven institutional flows were higher than the average for a town. For an insane hospital of 4500 inmates, the flow was 200 gal. per patient; for a tuberculosis hospital, 175 gal.; for smaller institutions, from 175 to 290 gal. Accurate measurements for an industry employing 2300 persons yielded flows ranging from 32 to 40 gal. per capita daily.

R. B. Morse said that in the Washington Suburban Sanitary District public schools use from 5 to 10 gal. per capita daily. In designing sewers for schools it should be remembered that although the amount of sewage is small it is discharged during a very few hours. In schools with resident pupils the per capita sewage may run higher than for a small town of equivalent population.

Sewer Rentals Pay for Treatment Plant

ANONYMOUS

Public Works, **63**, 21–22 (March, 1932)

ABSTRACTED BY H. W. STREETER

Hanover, Pa., a borough of 15,140 population, has a sewage treatment plant costing $79,827 and including a screen chamber, 2 Imhoff tanks, lime feed and chlorinating apparatus and sludge beds with pumps, meters, etc. The designers provided for sprinkling filters costing $100,000 and

additional sludge beds costing $10,000, as soon as money is available. The present plant has an estimated capacity of 20,000 persons and, on this basis, has cost $4 per capita. With the additions planned, the cost would be $9.50 per capita.

An average of 2.0 cu. ft. of screenings per m. g. of sewage are removed by the bar screens and put into the Imhoff tanks. Sludge is digested 8 to 12 days. Dry sludge is removed from the beds monthly at a cost of $12. It is hauled to a tract of public land.

The total cost of operating the plant in 1931 was $4753, of which $3149 was for labor and $612 for power. In addition $247 was spent for improvements to grounds and buildings. The operation cost per capita was 32 cents and per m. g. of sewage, $13.70. Interest and depreciation would add $18 or $20 to this figure.

The operation of the plant and sewerage system is paid for from sewer rentals, which totaled $20,474 in 1931, from 2469 sewer services, an average of $8.30 per service. Annual rates for residents include, in part, the following items: 1 water closet, $1.25; each additional closet, $1; bath tubs, $1 each; 1 kitchen sink, $1.10; each additional kitchen sink, 60¢; laundry tubs, urinals and shower baths, 75¢ each; cellar drains, $1.50 each. Rates outside the borough limits are 60 per cent greater.

The general maintenance of the sewer system costs $4000 per year, bringing the total operating cost of collection and treatment to $9384, or 62¢ per capita annually. The remaining $11,000 of income is applied to interest, sinking fund, etc., amounting to $3\frac{1}{2}$ per cent of $300,000, the present value of the entire system.

Sewer Rentals at Ardmore, Pa.

ANONYMOUS

Public Works, **63**, 22 (March, 1932)

ABSTRACTED BY H. W. STREETER

Lower Merion Township, Pa., of which Ardmore is the chief municipality, has provided by ordinance for the establishment of rates charged to all properties using the public sewers. For 1930 the sewer rental bills totaled $108,029 and the sewer costs $107,834, of which $70,903 was for operation and maintenance and $39,931 for interest and sinking fund. The system includes 5 pumping stations and 248 miles of sewers.

The sewer rental rates resemble the "flat rate" used by some water works, the annual charges including $3.50 for the first sink and $1.50 for each additional sink, $2.50 for each water closet, $1.50 for each bath tub, $5 for a one-car garage drain and $10 for two or more cars. There are

20 standard rates, with special ones for commercial services. Charges against churches and private homes are discounted 30 per cent, with a minimum rental of $4. Delinquent bills are placed with the town solicitor and if not paid within 3 years, are filed against the delinquent properties. The total of such delinquent bills in January, 1931, was $18,956, or 16.6 per cent of the total rentals for the year.

Progress in Sanitary Engineering

Report of American Society of Civil Engineers Committee on Progress and Status of the Art of Sanitary Engineering

BY LANGDON PEARSE, G. GALE DIXON AND W. L. STEVENSON

Civil Engineering, **2**, 164 (1932)

ABSTRACTED BY FRANK C. TOLLES

Progress in sewage treatment is listed as including (*a*) development of equipment, (*b*) research in sludge digestion, and (*c*) sludge dewatering.

Reference is made to the following as developments:

Grit Chambers.—The use of different types of cleaning mechanisms, the washing of grit and the possible centrifuging and incineration where mash is a factor.

Grease Removal.—Increased attention to this phase of sewage treatment and by the use of hand or mechanical skimming with or without preparatory agitation. The 1931 Report of the Committee on Sewage Disposal of the American Public Health Association is alluded to under this topic.

Sedimentation and Chemical Precipitation.—Competition between revolving and straight-line types of cleaning mechanism still obtains and requires the accumulation of operating data to define the suitability of each type. There is a difference in behavior in the settling of fresh solids and of activated sludge. Designs and rates of flow should be such as to avoid eddies. Reference is made to the reappearance of chemical precipitation.

Sludge Digestion and Drying.—The popularity of separate sludge digestion is increasing but with a need for more data from large installations: Floating and fixed covers, and tanks with and without stirring are still in the field.

Glass covers for sludge drying beds are becoming more common in the smaller plants but apparently they do not adhere to any fixed principles of design.

Mechanical Cleaning of Sludge Beds.—The Chicago West Side plant is

a radical departure from current practice in that it involves machine removal of dried sludge from large open drying beds.

The sludge problem has prompted consideration of the possibility of dewatering sludge as by vacuum filters and then incinerating the solids.

Activated-Sludge Process.—Trickling filter plants and activated-sludge plants are those most commonly used where complete treatment of the sewage is required. The digestion of mixed fresh and excess activated sludge has quickened interest in activated sludge. The importance of preliminary settling in this process is recognized. Aeration with diffused air is preferred in the larger plants, but mechanical agitation is appearing in the smaller works.

References.—Reference is made to research and experimental work at various centers as follows:

Large Scale Research	Sanitary District of Chicago Milwaukee Sewerage Commission Baltimore Treatment Works
Stream Pollution	U. S. Public Health Service
Filtering Digested Sludge (Vacuum Filters)	Sanitary District of Chicago Milwaukee Sewerage Commission Cities of Baltimore and Columbus
Incineration of Sludge and of Screenings	Milwaukee Sewerage Commission
Stage Digestion	Los Angeles County Sanitation Districts
Grease Skimming	City of Los Angeles
General Research	Illinois State Water Survey Iowa State University Massachusetts State Board of Health Michigan Agricultural Experiment Station New Jersey Agricultural Experiment Station U. S. Public Health Service Harvard Engineering School University of Illinois

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Sewage Disposal in the City of Tokio

BY Z. HARA AND K. HIRONAKA

World Eng. Congress, Tokio, **12**, 1929; *Public Works*, **39**, Part 4

British Summary of Current Literature, Water Pollution Research Board, Abstr. No. 642 (May, 1932)

The sewerage system of Tokio covers an area of 8230 hectares, serving a population of 3,440,000 and is divided into 3 drainage districts with separate disposal works. The sewage is discharged into the sea or river after screening and sedimentation. Experiments are being made on the acti-

vated-sludge process by mechanical agitation and by air blowing. Four to six hours' preliminary sedimentation does not improve the efficiency of the activated-sludge process. In the mechanical agitation systems, agitation or splashing of the mixed liquid at the water surface is essential and circulation in long channels is less effective except for mixing the liquid and sludge. By shortening of circulation channels with reduction of 78 per cent in volume of aeration tank, the period of aeration and power were reduced without affecting the percentage purification. When part of the activated sludge is allowed to settle at the bottom of the aeration tank, the sludge decomposes without affecting aeration and the excess sludge decreases considerably. Plans of the sewerage system and disposal works are given.

London County Council: Annual Report, 1930

Vol. 3, Part 1. Public Health (Report for the year 1930 of the County Medical Officer of Health)

BY F. N. K. MENZIES

British Summary of Current Literature, Water Pollution Research Board, Abstr. No. 633 (May, 1932)

In the section dealing with the work of the chemical branch (pp. 56–63), it is noted that the condition of the upper Thames tideway appears to be deteriorating; in hot weather in 1930 it was necessary to treat sewage effluents with ferrous sulphate. A brief description is given of the new sewage works at Beckton providing aeration of settled sewage in two-tier channels, settlement in hopper-bottomed and Dorr tanks, and reactivation of sludge by diffused air. Laboratory experiments on (sludge) digestion at 55° C. have indicated marked reduction in the digestion period, without such an increased gas production as would supply the additional heat requirements. A large-scale experimental sludge digestion tank is to be constructed.

Disposal Critical for Beet Sugar Industry

Chem. Met. Eng., **38**, 542 (1931); *British Summary of Current Literature, Water Pollution Research*, Abstr. No. 665 (May, 1932)

The amount and composition of waste waters from beet sugar factories, including those from the Steffen lime process of sugar precipitation from molasses, are discussed. Volumes of waste water are greater in American than in European factories and the use of return water is regarded as injurious to the final product. The disposal problem is not so acute in America as in Europe as factories are generally in sparsely populated

districts near large rivers. Although no process so far examined appears to be generally suitable, separation of the different types of effluent with settlement and re-use of fluming and washing water and settlement, in series of ponds with riffled overflows, of the press water and lime wastes before discharge is recommended as giving most satisfactory results at lowest cost.

Fluorescence in Relation to Sewage

BY J. A. RADLEY

Analyst, **57**, 28, No. 670 (1932); Abstr. No. 663, *British Summary of Current Literature, Water Pollution Research Bd.* (May, 1932)

Sewage, sewage effluents and sludge in various stages of digestion were examined in filtered ultra-violet light in which only wave lengths of about 3650 A. U. were allowed to pass. Sewages and effluents all gave a blue fluorescence due partly to suspended and partly to dissolved substances. Fresh crude sludge appears very dark and has a faint fluorescence with a number of intensely fluorescent specks due apparently to particles of fat and cellulose which disappear as digestion proceeds. There is apparently no relation between intensity of fluorescence and oxygen absorption (4 hrs.) or free and albuminoid ammonia content of sewage. The lamp has no advantages over the usual methods of sewage analysis, or of determination of the stage of sludge digestion. Experiments on the fluorescence of the flora and fauna of filter beds are in progress.

Detection of Sulphite Waste Liquor in Sea Water

BY H. K. BENSON AND W. R. BENSON

Ind. Eng. Chem., Anal. Ed., **4**, 222 (1932)

ABSTRACTED BY P. D. MCNAMEE

The presence of sulphite waste liquor in sea water cannot be detected by a simple chemical analysis. An estimation of the amount of sulphite waste liquor in sea water can be obtained by considering the oxygen balance, pH, sulphate-chloride ratio and the color. The oxygen balance is obtained by subtracting the biochemical oxygen demand value from the dissolved oxygen content of a sample taken simultaneously. It was found that 133 p. p. m. of sulphite digester waste yield negative values. A measure of the pollution is obtained by comparing the oxygen balance of the sample with that of unpolluted sea water from the same locality. The acids present in sulphite waste reduce the alkalinity of sea water. Owing to the

presence of buffering agents in the sea water, a simple pH determination is not a reliable indication of the amount of pollution. The amount of acid necessary to yield a constant pH of approximately 4.0 when compared with the amount for unpolluted ocean water (23 to 26 ml. of 0.01 *N* acid per 100 ml. water) gives a measure of the acidic constituents not normally present in ocean water. The presence of sulphite waste liquor gives a higher sulphate-chloride ratio to sea water. The sulphate-chloride ratio of sea water changes from 0.141 to 0.163 on the addition of 4 per cent of sulphite waste liquor. Sulphite waste liquor imparts color to sea water but the presence of other coloring agents in the sea water frequently invalidates results based on color tests alone.

Distributors for Sprinkling Filters

BY PAUL SCHRAMM (MICHELBACH-NASSAU)

Gesundh. Ing., **55**, 265 (June 4, 1932)

ABSTRACTED BY G. P. EDWARDS

Sprinkling filters are used for secondary purification of sewage because of the satisfactory results, the simple supervision required and the low operating cost, which is about one-fourth of that for activated sludge. Aeration of the sprinkling filter is aided by providing a grate of iron bars as a floor and this is covered by a layer of stones 16 to 18 cm. in size.

An old type of dosing tank contains a swinging arm through which the sewage enters. The arm acts as a float so that when a definite level is reached, a valve shuts off the flow and the tank empties through the arm. This arrangement is very inefficient as the loss in head amounts to about 60 per cent. Newer types of this apparatus have reduced the loss in head by avoiding this reversal in flow through the swinging arm and by using pipe of uniform cross section.

In the rotary distributors, efficiency as well as accessibility to the ball-bearing and mercury seal is very important. In the newer types of construction, the mercury seal is protected from sludge particles. By substituting a lifting screw for the brass bearing plate, the distributing arms can easily be raised by one man, for control and cleaning the bearing. In older types of this apparatus, two or four men were required for this work. A trap filled with oil may be necessary to protect the bearing in plants having trouble with flies.

For large installations, traveling distributors are satisfactory, although in Germany, rotating distributors, with fixed nozzles placed in the areas between the circles, are preferred because of the certainty of operation and the uniform distribution. The disadvantage of the traveling distributor, in that the ends of the field are more heavily dosed than the

center, can be overcome by using a field of suitable length and by dosing in strips.

Distributors for Sprinkling Filters.—One type of traveling distributor has an Elt pump mounted on a movable frame. The pump pressure furnishes the power for moving the distributor and its weight is very small. The apparatus is reversed by a simple valve construction.

In small plants, troughs, dosed by a tipping bucket, may be used for distributing the sewage.

If the sewage must be pumped, nozzles are most satisfactory. A pump feeding directly to the nozzles can be used. Intermittent flow can be obtained by automatic float valves.

Sewage Treatment in United States Compared with That at Los Angeles Experimental Station

Part I

BY R. F. GOUDEY

Water Works and Sewerage, **79**, 67–70 (March, 1932)

ABSTRACTED BY H. GLADYS SWOPE

Since May 12, 1930, Los Angeles has operated continuously a 200,000 gallon per day complete activated-sludge separate-digestion plant, reclaiming one-third of the effluent by purification in a water filtration plant.

Southern California sewage is very concentrated, becoming septic before reaching the treatment plant and therefore the biological activity involves the sulphur and carbon cycles as well as the nitrogen.

The author states, after visiting small or medium sized plants in the East and along the Atlantic coast, that the eastern plants consider treatment passable if the effluent is good under average rainfall conditions. This, he feels, gives a heavy load on certain streams during periods of abnormally low rainfall. He states also that: "The East is very slow in adopting new applications of mechanical devices." He applies this latter statement to the fact that paddle aeration has not been used and that chlorination was not used to any large extent; whereas in California almost every high grade treatment plant is equipped with chlorinators.

Part II

Water Works and Sewerage, **79**, 177–80 (May, 1932)

This paper deals with the design and operating features of the activated-sludge process.

The author states that it is the policy of the Los Angeles Experimental Station to avoid past errors and to develop new ideas. "This work is rapidly leading to the production of a super-activated sludge process. It is one in which the sludge during reaeration is adjusted to the proper ratio of bacterial and protozoal life in reference to food supply, one in which chlorine plays an important part in the liberation of enzymes, one in which pH is carefully watched in the incoming sewage, one in which bulking of sludge is of no concern whatever, and one in which the oxidation requirements are more carefully watched than elsewhere."

The activated-sludge process is discussed under the following headings: screening, preliminary clarification, sewage aeration, reaeration, final sedimentation, sludge digestion, gas production and utilization, and sludge disposal.

Los Angeles is now experimenting with aerators such as buckets on paddles, use of air lifts in the center of aeration tanks and aeration from rotors of the Genter type (compressed air discharged through a revolving perforated rubber cylinder). When using 35% returned sludge the aeration period may be shortened to 4 hours and nitrification may be obtained with a detention period of 2 hours when using what the author terms "super-activated" returned sludge. Sludge is diluted with the final effluent until good flocculation occurs and then returned to the settled sewage for aeration.

Trends in Sewage Treatment in 1931

BY F. W. MOHLMAN

Water Works and Sewerage, **79**, 33–37 (Feb., 1932)

ABSTRACTED BY H. GLADYS SWOPE

As the disposal of sewage solids is the difficult problem in sewage treatment, progress in the latter is therefore largely measured by progress in methods for the disposition of the solids. The year 1931 was noteworthy for new developments in sludge disposal. Research has been carried on to determine the economic feasibility of mechanical filtration and incineration of sludge. Glass-covered sludge beds and sludge storage tanks have been installed in new plants. Sludge digestion in heated tanks is the most widely studied problem of sewage treatment. On the Pacific coast sewage has been reclaimed for irrigation purposes. Chemical precipitation has again come into the limelight.

The Status of Sludge Digestion.—It was only five years ago that the first complete heated sludge digestion plant was put into operation in the United States and yet there are now over fifty in operation. Thermophilic digestion (125° F.) has been studied on a large scale at

Aurora, Illinois, Los Angeles, California, and Plainfield, N. J., and at several places on a laboratory scale. The disadvantages, however, are a very concentrated and extremely odorous supernatant liquor, and a sludge which is also odorous and does not drain rapidly. Dr. Ardern at Manchester, on the other hand, has had encouraging results on sludge from strictly domestic sewage. Most digestion tanks are operated at a temperature of 95° F., the heat being generated from gas produced during digestion process.

The introduction of fresh solids into an actively fermenting mass in the digestion tank causes a violent ebullition of gas and such undesirable after-effects as: excessive moisture content of sludge withdrawn; highly concentrated supernatant liquor, which is difficult to dispose of; and short-circuiting resulting in some undigested solids being withdrawn. Consequently the universal practice now is to return excess activated sludge to the influent of the primary settling tanks. The moisture content of the mixed sludge will average between 94 and 96%, whereas activated sludge averages 98.5 to 99% and settled solids 95 per cent.

The supernatant liquor has been known to contain as high as 15,000 p. p. m. suspended solids. This concentration can be reduced by operating the digestion tanks in series and displacing the liquor from the second or last tank, only; or by introducing sludge for a period and withdrawing supernatant liquor later. At Essen-Rellinghausen, Dr. Imhoff had two tanks in series, the first heated, with 18 days' storage capacity, and the second unheated, with 26 days' capacity.

Disposal of Digested Sludge.—At the Grand Rapids, Michigan, Peoria and Chicago, Illinois, plants, the primary digestion tank provides for 30 to 50 days' digestion with heat, followed by 4 to 5 months' storage in an open tank. At Chicago, it was found that during the storage period the solids became more concentrated.

Glass-covered sludge beds have become more popular, particularly in Ohio. With sludge from digested crude solids, a sludge of 63% moisture can be removed in 17 days at Dayton. At North Toronto the moisture content of sludge from mixed solids is 80% when removed from the beds.

Mechanical Dewatering of Sludge.—At Chicago, the possibility of filtering mixtures of fresh solids and activated sludge has been studied in an effort to eliminate digestion completely. It was found that fresh sludge filtered on an Oliver filter at higher rates and with less expense for necessary coagulant (ferric chloride) than was required for digested sludge. A large test plant has been designed with a capacity of 20 to 30 tons per day to study this problem further. Filtration of mixed sludge (fresh and activated) is preferable to activated sludge alone, as the moisture content is lower and the vacuum filters can be operated at higher speeds. Rates of filtration range from 2 to 9 lb. per sq. ft. of filter area per hour.

Incineration of the filter cake should provide a satisfactory method of final disposal. The B. t. u. value of undigested sludge is between 6000–7000 on the dry basis, whereas digested sludge is much less.

Chemical Processes.—Ground paper pulp has been used with activated sludge before filtration on vacuum filters. Lime, ferric chloride and paper pulp have been used as a mixed coagulant for the purification of sewage at Dearborn, Michigan. Chlorine has been used for precipitating packing-house wastes.

Activated Sludge.—This process is superior to all others for large treatment works, as is evidenced by the large plants at Milwaukee, Chicago, Providence, Ward's Island and Cleveland. The new Peoria plant is designed for treatment of sewage from 140,000 population and in addition, partial treatment for 8 m. g. d. of industrial wastes. With the exception of Milwaukee, all have spiral-flow aeration tanks.

Preliminary sedimentation is standard practice, in tanks equipped with mechanical cleaning devices. Some of the smaller plants use mechanical aeration in conjunction with diffused air.

The use of mechanical distributors for trickling filters may become more common in the United States in the next few years.

California Sewage Works Journal

Volume 4, No. 1, 1931

ABSTRACTED BY H. GLADYS SWOPE

The papers appearing in the above journal were presented before the fourth annual meeting of the California Sewage Works Association held at Monterey, California, September 21–22, 1931.

Some Practical Improvements in Operation Resulting from Research at Griffith Park Experimental Station, Los Angeles. By R. F. GOUDEY. The greatest bug bear to the activated-sludge process is the large amount of sludge produced and its high moisture content (99.5%). With preliminary sedimentation the excess activated sludge amounted to 15,000–20,000 gal. per m. g. of sewage treated as compared with 15,000–50,000 gal. when preliminary sedimentation was not employed. The volume was further reduced if the excess activated sludge was pumped back to the primary settler at a low and uniform rate, obtaining as low a total volume of fresh and activated sludge as 6800 gal. per m. g. of sewage treated. If this material was thickened before or after digestion the volume was still further reduced. Drying the sludge on sand beds is slow and acreage needed is very large. It was found profitable to condition the digested sludge with ferric chloride and dewater by vacuum filters

to a moisture content of 65–80%, followed by drying to 10% moisture. Thermophilic digestion was found to be very unsatisfactory.

The overflow liquor from digestion tanks was removed from the bottom of the digestor into a storage tank simultaneously with the pumping in of fresh sludge. When the storage tank is full it is emptied on sand beds, thereby eliminating any overflow liquor.

Clarifiers used for preliminary sedimentation of sludge should be designed on the basis of surface area and not on the detention period as is evidenced by the following: 1500 to 2500 gal. per sq. ft. per day gave 30–40% removal of suspended solids; 935 gal. gave 55–60% and the Griffith Park station using 615 gal. per sq. ft. per day gave 80% removal. Clarifiers operated as upward flow tanks are best for settling activated sludge.

In the aeration tanks, air is supplied through buckets placed on the ends of the paddles, thus releasing air in the lower portion of the tank.

Sludge bulking has been controlled by chlorinating the returned sludge, and adding a portion of the final effluent, plus settled sewage, before reaeration.

The State Department of Public Health and Its Relation to the Sewage Works Operator. By GILES S. PORTER, M.D. Dr. Porter states that the Department of Public Health of the State is finding its personnel too limited to be able to check up each sewage treatment plant more than once in several months and therefore it is the duty of each city to see that its officials are informed and look after the plant intelligently or to employ some one for that purpose.

Yosemite Valley Activated Sludge Plant. By H. B. HOMMON. The Yosemite Valley occupies an area of 1162 square miles. As in all other national parks it has a fluctuating population due to tourists, the heaviest being during the summer months. The first treatment plant was built in 1921 and consisted of Imhoff tanks, sand filters and sludge-drying beds. Four pumping stations were also operated. The plant was designed to care for a maximum of 750,000 g. p. d. In 1930 the plant caused trouble due to overloading and odors became very obnoxious.

In August, 1931, the new plant was put into operation. This plant is located on the south side of the valley between the Merced River and the highway and one-fourth mile from the foot of Bridal Veil Falls. It comprises a bar screen; a covered concrete primary settling tank without baffles; four aeration tanks, 50 by 18½ ft. with an effective depth of 12 ft.; two clarifiers operating in series; chlorination of effluent from the second clarifier; a thickening tank for mixing the sludge from the primary tank and the first clarifier; three sludge-digestion tanks fitted with heating coils and concrete gas domes; glass-covered sludge-drying beds; storage tank; gas holder and laboratory.

The average of 15 samples of effluent from the final clarifier showed a dissolved oxygen content of 6.1 p. p. m.; B. O. D., 2.1 p. p. m.; alkalinity, 25 p. p. m.; and free chlorine 0.3 p. p. m. The effluent from the aeration tank gave a nitrate content of 0.21 p. p. m.

Advances in Sewer Pipe Construction. By A. M. RAWN.

Legal and Other Considerations on Sewer Rental. By WM. J. LOCKE. Some of the very old sewer systems were installed under the coöperative plan, each property owner paying a portion of the expense. From an examination of court decisions in this country private sewer companies have been financed by charges imposed upon users. In the case of Madera, Calif., there was a sewer system owned by a private corporation in 1908 which was taken over and paid for by the city. From 1909–16, the city charged people for the use of the system. In 1916, a party objected to the right of said city to collect since the system was installed by a bond issue. The city won in the lower court but it was appealed to the supreme court and the city lost.

The author feels that any special service the sewers are used for, such as industrial wastes which harm effective treatment of sewage or in cases where owners are taxed for maintenance of a sanitary district on *ad valorem* basis, that service charges are certainly legitimate.

Sewage Disposal Out of California. By CLYDE C. KENNEDY. Mr. Kennedy outlines particular features of sewage plants visited between the Alleghany and Rocky Mountains. Separate sludge digestion was superceding Imhoff tanks and the beautification of treatment plants is becoming an essential part of the work.

Sewage Disposal Out of California. By WM. A. ALLEN. The author gives a very short résumé of notes on the Springfield, Illinois; Indianapolis, Indiana; Rockville Center, Long Island; Salem, Ohio; Peoria, Illinois; Milwaukee, Wisconsin; and the North Side Plant at Chicago, Illinois.

"Slipseal" Precast Ashphaltic Sewer Joint. By E. FRENCH CHASE.

Refined Sewage Treatment Is Justified. By CARL WILSON. A general discussion of the justification of complete sewage treatment to the extent of reclamation.

Sewerage Improvements, Phoenix, Arizona. By W. J. JAMIESON and CLYDE C. KENNEDY. The first treatment plant was built in 1910 and consisted of a double unit, Cameron-type septic tank designed for one-fifth of the present flow. In August, 1930, plans were laid for a new plant consisting of bar screen equipped with a Dorrco type cleaning mechanism, screenings hopper and overhead track and conveyor to transport the hopper to a truck-loading door in the building housing the bar screen; Venturi flume; primary clarifier equipped with Dorrco traction type mechanism for sludge removal, five primary aeration tanks and one reaeration tank, each unit being equipped with two Imhoff-Dorrco paddles extending the

full length of the tank; secondary clarifier and chlorination dosage channel. The sludge from the primary clarifier will be pumped to a sludge thickening tank into which is also discharged the excess activated sludge. From this thickener the sludge is pumped to two digestors. The digested sludge will be dried on sand beds. (See THIS JOURNAL, p. 525, May, 1932.)

Salinas Sewage Treatment Plant. By T. R. HASELTINE. The population of the city is 10,000, with an average sewage flow of 620,000 gallons per day. The sewage is a strong domestic sewage with a very high grease content.

The primary settler removes 52% of the suspended matter, 27% of the B. O. D., 13% of the total nitrogen and 27% of the total grease.

The excess activated sludge is discharged to the crude sewage.

No seeding material nor lime was used at the start of digestion and a pH of 7.0 was obtained in 80 days and a daily gas production of 8000 cu. ft. was developed in 95 days after the digestor was filled. During the first 7 months little activated sludge was digested but when this was added the gas production increased 40% to 60%, a decrease from 10% to 5% in the solids content, and a decrease in the volatile matter reduction from 55% to 33%. The temperature of the digestor has ranged from 61° to 71° F. The pH values without liming have ranged from 6.8 to 7.0. The gas yield has averaged 5000 to 8000 cu. ft. per day during the winter and 8000 to 13,000 during the summer. The gas has an average heating value of 650 B. t. u. per cu. ft.

The aeration tanks are of the spiral-flow type and two tanks are operated in parallel. As the sewage is unusually strong a great deal of difficulty occurred in the aeration units in trying to build up a good sludge and later with bulking. To get rid of the latter difficulty more returned sludge had to be used. Wooden baffles were also placed in the aeration tanks to deflect the rising air and mixed liquor above the filtros plates. Average analyses of the final effluent shows it to contain 22 p. p. m. suspended matter, 27 p. p. m. 5-day B. O. D., 4 p. p. m. organic nitrogen, 19.5 p. p. m. ammonia nitrogen, 1.5 p. p. m. nitrite nitrogen and 5.2 p. p. m. nitrate nitrogen. The effluent from the aeration tanks passes into two final clarifiers operated in parallel and thence into the Salinas river.

The following papers appearing in the California journal were published in THIS JOURNAL:

"Aeration Experiments and Experiences at Salinas, California." By T. R. Haseltine, **4,** 461 (May, 1932).

"Operation of Typical Sewage Disposal Plants in California and Comparison with Results Obtained Elsewhere." By E. A. Reinke, **4,** 83 (Jan., 1932).

"Sewer Ventilation, Why and How." By D. Donaldson, **4,** 108 (Jan., 1932).

"Explosions in Sewers and Sewer Maintenance." By W. T. Knowlton, **4,** 114 (Jan., 1932).

"Control of Cannery Odors at Monterey." By H. D. Severance, **4,** 152 (Jan., 1932).

"Recent Studies on Sludge Digestion." By A. J. Fischer, **4,** 44 (Jan., 1932).

Modern Sewage Treatment*

BY T. P. FRANCIS

REVIEWED BY S. I. ZACK

"Modern Sewage Treatment" deals with the subject of sewage treatment in an interestingly written manner. It is composed of material of general descriptive or academic, rather than of specific or detailed nature, and contains a unique collection of several hundred photographs, drawings and diagrams of sewage treatment works and equipment in different parts of the world.

The text is divided into (1) twelve chapters, covering practically all phases of treatment, including dilution, preliminary treatment, sedimentation, final treatment, disposal of sludge, storm water and trade wastes, small plants and practice abroad; (2) description of about 13 English sewage treatment works; and (3) appendices on sewage chemistry, pH, colloids, biology, air machines, pumps and flow computations, typical examination questions and German equivalents. A summary particularly suitable for student use is included at the end of each chapter and each appendix.

This book is written chiefly from the standpoint of English practice and Ministry of Health requirements, but sufficient references by means of photographs and text are also made of developments in America and Germany to cover the field of sewage treatment as it exists at the present time.

The photographs and other figures are of extreme interest and aid materially in giving a perspective of the material covered. A criticism, however, might be made of their random distribution throughout the book without direct reference to them in the text.

The following is a brief review of some of the more important features included in the various chapters and appendices:

The analogy of agricultural processes to sewage treatment is made, and the Royal Commission recommendations on dilutions of 500 for raw sewage and 300 for effluents containing 150 p. p. m. suspended matter are given.

* Published by the Contractors Record, Ltd., 329 High Holbom, W. C. I.

Preliminary treatment includes grit chambers, screens, skimming and septic tanks. Description of their purpose and a few design features at plants in Germany and England are given, without inclusion of quantitative information regarding these plants. American practice on this subject is rather brief.

Ministry of Health requirements for sedimentation with and without chemicals are stated to be more conservative than generally accepted at the present time outside of England. The theory and operating features of Imhoff and settling tanks with and without mechanical removal of sludge are outlined, Link-Belt, Dorr, Mieder and Prüss tanks being included in the latter.

Land irrigation and filtration contact beds, percolating filters, biological aeration and aeration plants are described in three chapters. The author's analyses of the theory and mechanics of these processes are written in a style which gives a clear and concise conception of the principles involved. Data on practical applications such as $1^1/_3$ to 3 cu. ft. of air per gallon of sewage and 4 to 30 hours' aeration are somewhat too general to be of specific value for purposes of design.

Descriptions and estimates of power required by mechanical aeration processes, including paddles plus diffused air, Sheffield, Simplex, Kessener, Hartley "Spiroflow" and Link-Belt aerators, show the trend and progress of treatment by activated sludge.

Sludge treatment includes disposal at sea, on land and dewatering. Arbitrary figures are quoted on British practice of area of land or beds required for sludge disposal. Reference is also made to drying sludge on glass-covered beds and mechanical removal of sludge from open beds in America.

The theory and practice of sludge digestion including the various controversial questions are outlined. Buswell, Prüss, Imhoff and O'Shaughnessy and others are quoted. In conclusion, it is stated that (1) the factors of digestion for maximum gas production are: appropriate inoculation of sludge, constancy of optimum temperature of 75° to 85° F., pH of 7.3 to 7.6, adequate mixing to insure even distribution; (2) gas production should be 0.55 to 0.85 cu. ft. per capita per day; (3) only 1 cu. ft. per day of fresh sludge can be added to 30 cu. ft. of digesting sludge; (4) tank capacities per capita to be allowed are Germany—1 cu. ft.; America—2 to 3 cu. ft.; and England—$1^1/_2$ to $2^1/_2$ cu. ft. The requirements for digestion of activated sludge are not mentioned. Results in America indicate the need of a considerably greater capacity for digestion of a combination of freshly settled sludge in combination with activated.

Ministry of Health requirements for handling storm flow are briefly mentioned. A few pages are devoted to some of the more important factors relative to trade wastes and their general effect on sewage treat-

ment as well as the practical policies to be followed with respect to the industries.

Sewage treatment abroad is exemplified by descriptions of plants in America, South Africa, Germany, France, Belgium, Holland and India. The American plants described are the Rockville Center Plant, Long Island, the Watsco aerator, Montezuma, Calif., and "stream flow aeration" for trade wastes applied by Levine, Nelson and Jenks.

Nearly 100 pages are devoted to descriptions of English works, either contributed by the various officials or abstracted from their reports. This portion deals primarily with the construction and operation features of these plants in considerable detail and in a few instances gives some of the analytical results.

The outline of sewage chemistry and the description of pH, colloids and biology of sewage are enlightening and help the engineer to understand some of the phenomena of sewage treatment.

The description of air compressors, pneumatic ejectors, air lift pumps, flow measurement, centrifugal and unchokable pumps, and power for pumping, very appropriate for a book on sewage treatment, are included in the appendices. Although the British practice as outlined may vary in many instances from the American, the differences are well worthy of being observed.

This book describes clearly and concisely the theories, functions and operations of processes and equipment, brings to the attention of the sewage worker the recent trend and illustrates the new developments of mechanical equipment for use in sewage treatment.

Notable Planning Characterizes Morristown's Sewage Treatment Works

BY WESTON GAVETT

The American City, **46**, 68 (May, 1932)

ABSTRACTED BY E. HURWITZ

In laying out the new Morristown plant all the units of the old plant with the exception of one contact bed were left intact. Three of the original settling tanks are now being used for sludge storage; the fourth has been fitted with a Hardinge apparatus for removal of sludge and floating material and is used as a preliminary settling tank. The original sand filters and chlorinating apparatus have been kept in service. The new additions to the plant are aeration units, additional sludge digestion tanks, final settling tanks, blower house and chlorine detention tanks.

The aeration tanks have a capacity of 2 m. g. d. with a $6^1/_2$-hour deten-

tion period and 20 per cent return. The final settling tanks are of the vertical flow type and provide a two-hour detention period. Excess sludge is wasted to the digestion tanks where it is digested with the sludge from the preliminary tanks.

The digestion tanks have a capacity of 40,000 cu. ft. or 2 cu. ft. per capita; additional tanks provide 35,000 cu. ft. of storage. Provision is made for heating and gas collection.

Air is supplied by three 100 c. f. m. positive pressure type blowers, each direct-connected to 30 hp. motors. A gas-engine driven generator provides stand-by service.

Motors, blowers, pumps, heating units, etc., are housed in a building of colonial design in keeping with the historic environment of the plant.

Sewage Treatment Works Built During Period of Low Prices

BY V. W. WHITFIELD

The American City, **46**, 83 (May, 1932)

ABSTRACTED BY E. HURWITZ

The City of McPherson, Kansas, has taken advantage of low labor and material costs to secure a modern sewage treatment works. Two totally inadequate old plants were abandoned and a trickling filter plant preceded by clarification, with separate-sludge digestion was erected.

Sewage flows into a combined pump well and screen chamber from where it is pumped to a Link-Belt clarifier having a two-hour detention period at maximum flow. The clarifier effluent is then passed onto a filter bed equipped with rotary distributors and from there to the final settling tanks.

Sludge from the clarifier and final settlers is pumped to Hardinge equipped digesters. These have a total capacity of 2 cu. ft. per capita. Provision is made for utilization of gas generated for heating purposes. Digested sludge is dried on beds.

The contract called for hand labor on the new outfall sewer and specified that all common labor should be drawn from McPherson residents. In spite of these exactions the contract bid was far under the anticipated cost.

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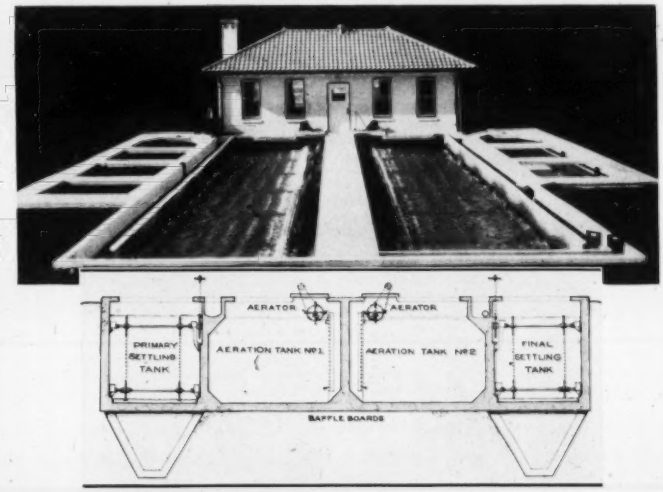

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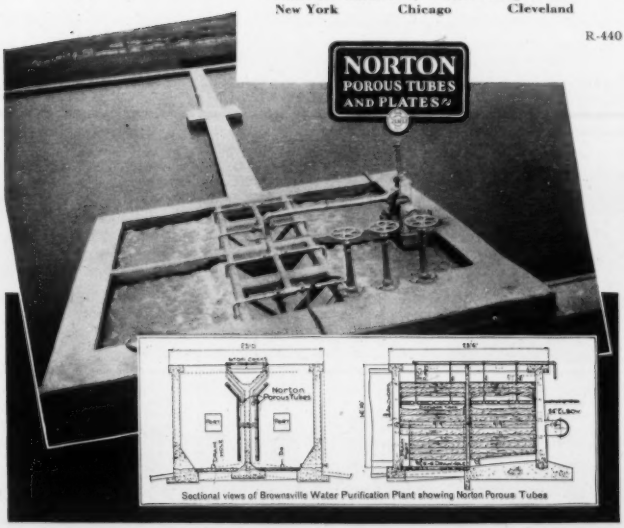

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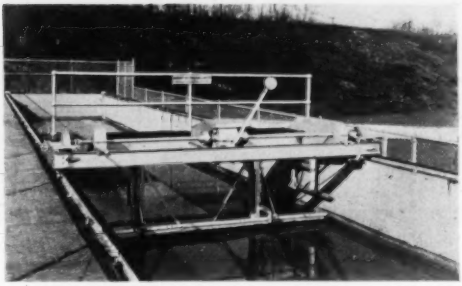

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A scum skimmer at the surface operates in a similar manner. The surface is kept clean of any unsightly collection of sludge on the tank edges or the moving parts.

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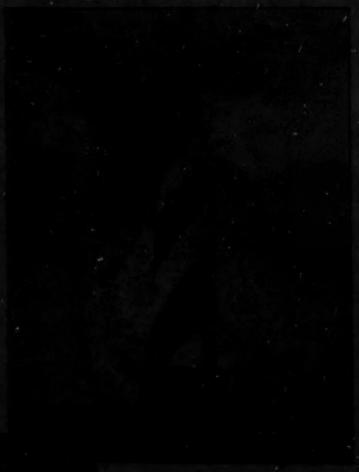
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